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GEOLOGICAL SURVEY OF KENTUCKY.

WESTERN COAL FIELD.

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COMPRISING SIX REPORTS ON THE RESOURCES
OF SOME OF THE COUNTIES LOCATED IN
THE WESTERN COAL FIELD.

STEREOTYPED FOR THE SURVEY
BY MAJOR, JOHNSTON & BARRETT.
YEOMAN PRESS, FRANKFORT, KENTUCKY.
1884.

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PREFACE TO SECOND EDITION (NEW SERIES).

It being necessary to publish a new edition of the Reports of the Geological Survey, it is thought proper to change the arrangement of the reports in the several volumes. This is advisable in order to bring together in one volume the several reports relating to a given subject or locality. In the first edition (second series) the volumes were made up of reports, regardless of subjects treated, and in order to learn all that may be published of a locality, the reader must examine several volumes. For instance, the reports on the iron ores and the iron manufacture of Greenup, Carter, Boyd, and Lawrence counties is in volume 1, and the Report on the Geology of the above named counties is in volume 2. The Chemical Reports and the reports on the Timbers are scattered through four volumes. This arrangement of reports could not have been avoided in the early history of the Survey without a delay in the publication of the volumes. It is thought that the arrangement in this edition will more fully meet the wants of the public, and will render the reports more valuable.

The first volumes of this edition will comprise the following: Chemical Analyses, Reports on the Eastern Coal Field; Reports on the Western Coal Field; Reports on Timbers. Other volumes will be published from time to time, preserving the same order of grouping reports. Some of the preliminary reports contained in the first edition have been omitted, in order that there may be no duplication when the final reports are published. I am of the opinion that enough preliminary or reconnoissance work has been done by the Survey, and the work will be directed with a view of securing (so far as the means will permit) complete reports on the geology, soils, timbers, etc., of the various regions

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studied. As the stereotyped plates of the omitted preliminary reports are preserved, new editions may be ordered should there be a demand for them. A change has also been made in the size of the volume by decreasing the size of the margin, which, it is thought, will make the volume a more convenient size, both for library use and for sending through the mails.

JOHN R. PROCTER,
State Geologist.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

REPORT ON THE GEOLOGY

OF THE

NOLIN RIVER DISTRICT,

EMBRACING PORTIONS OF

GRAYSON, EDMONSON, HART, AND BUTLER COUNTIES,

BY P. N. MOORE.

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INTRODUCTORY LETTER.

Professor N. S. SHALER, *Director Kentucky Geological Survey:*

I herewith transmit my report upon the geology of that portion of the western coal field between Green river and the Louisville, Paducah and Southwestern Railroad, lying east of Bear Creek. The limits of the work have been determined more by geological and topographical boundaries than by political divisions. It therefore embraces portions of Butler, Grayson, Edmonson, and Hart counties, without including the whole of any of them.

I desire here to acknowledge the valuable assistance rendered to the Survey by Mr. John R. Procter. In addition to his services in the field, Mr. Procter has been of great assistance in preparing the cross-sections which accompany this report. His observations have been extensively used in their construction.

Respectfully submitted,
P. N. MOORE, *Assistant.*

ON THE GEOLOGY OF THE NOLIN RIVER DISTRICT, EMBRACING PORTIONS OF GRAYSON, EDMONSON, HART, AND BUTLER COUNTIES.

The area covered by the present report consists of that portion of the western coal field, and the immediately surrounding country, which lies east of Bear Creek, between Green river and the line of the Louisville, Paducah and Southwestern Railroad.

SURFACE FEATURES.

This region, for one in which the vertical height of the hills is comparatively so small, affords considerable variety in its topographical features, which have been formed solely by erosive agencies slowly acting upon sedimentary rocks of various kinds, which are comparatively undisturbed, and lie nearly horizontally.

A great variety of forms of topography are presented, which offer fine illustrations of the effect of the different rock formations of a country upon its surface features by the different degrees with which the rocks resist erosion. Resistance to erosion has been alone the determining agency in forming the topography; it has not been appreciably affected by distortions, upheavals, or faults in the strata; for, taking the region as a whole, it is very little disturbed, and the rocks usually retain their original position, lying horizontally or dipping slightly to the west.

There are, it is true, in portions of this region, in the limestones and sandstones of the Chester Group, a large number of small faults, some of which extend up into the overlying coal measures; but they are usually of small vertical extent, rarely measuring more than 50 feet, and they do not seem to have exerted any appreciable effect upon the topography.

There are few prominent hills, but the general surface of the country may be best considered as a plain of considerable elevation, with the variations in height caused by the streams cutting through in different ways. The highest elevations will not exceed 490 feet above low water in Green river, at Brownsville, or 920 feet above tide water, estimating Green river at Brownsville as 430 feet above sea level–a level obtained from the best data at command, which, however, are imperfect. The general level of the country, on the ridges and comparatively flat uplands at the heads of the streams, is from 300 to 400 feet above Green river; while the level of the valleys, which in the lower part of this region are usually quite narrow, is from 200 to 250 feet below the uplands.

The drainage is all into Green river, chiefly through its two principal branches, Nolin river and Bear Creek, although there are a number of small creeks flowing directly into Green river, in the southern part of the region.

To the north, on the ridge which forms the divide between the waters of Rough Creek and those of Nolin river and Bear Creek, and along which the Louisville, Paducah and Southwestern Railroad passes, the surface of the country is level or gently rolling. To the south, it is much more broken, showing high table lands with the streams cut as deep gorges or cañons, with precipitous and often impassable banks, affording remarkably picturesque scenery.

The topography of the northern portion is due to the alternate thin sandstones, limestones, and shales of the Chester Group, which, not offering great resistance to the erosive agencies, are acted upon quite uniformly, giving us even and gentle slopes, except where there is a limestone or sandstone thicker than usual, when the streams cut narrow and gorgelike but shallow valleys, leaving the general surface above the streams still comparatively level and unbroken. On the south, a series of heavy, coarse sandstones, culminating in the massive conglomerate, which is from 100 to 180 feet thick, are the determining rocks, and give us a characteristic topography.

Where the massive sandstone forms the tops of the hills, and is underlaid by friable shales and shaly sandstones, we have for the uplands a nearly level surface, streams narrow and precipitous at the upper part, where each one heads in the sandstone, and wider below, giving occasional valleys which afford good-sized farms of nearly level land. This is the character of the topography over a large portion of this region—of nearly all of that north of Sycamore and Dismal Creeks to the edge of the coal measures. Here a massive, thick-bedded sandstone, ranging from 40 to 60 feet in thickness, lies near the surface, and gives character to the topography. All the streams head in it, or cut their way through it near their heads, where it shows many exposures of its full thickness, in precipitous cliffs.

Further south, the conglomerate sandstone is of great thickness, and the streams are cut in it and the underlying limestone. The result is, that they are little more than narrow but deep gorges for their entire length, with little or no tillable land even near their mouths. The walls of these gorges are often precipitous cliffs from 75 to 150 feet in height. The country is so cut up by streams of this class, that travel is very difficult or impossible, except by following the main ridges or divides between the streams.

Some of the most romantic and beautiful scenery of the State is to be seen on the streams of this region. The well-known Dismal Rock, on Nolin river, at the mouth of Dismal Creek, is but one instance among many. Piney, Pigeon, Bylew, and the other creeks in the heavy conglomerate, present a series of wild and picturesque cliffs which have been rarely seen by appreciative eyes, but are well worthy the attention of the tourist. Were they more accessible, the region would doubtless become a well known and attractive resort. As it is, some of the finest scenery is but a short ride from Mammoth Cave, and can readily be visited from that place.

Nolin river, from Dismal Creek to its mouth, cuts its way through the heavy conglomerate. Its valley, which above had been at some places of considerable width, at once narrows, and at many places is little wider than the bed of the stream; and the banks are so steep that it is with difficulty one can make his way along them. In this distance, at almost every turn, abrupt, precipitous cliffs tower above the stream from 150 to 200 feet high, and some even higher. Among the best known of these are Dismal Rock, at the mouth of Dismal Creek, on the very edge of the thickest conglomerate, Bylew Rock and Whistling Mountain, one on each side of the mouth of Bylew Creek. A sketch of Dismal Rock is given by Dr. Owen in the first volume, first series, Kentucky Geological Reports.

To the east we have the topography determined by the heavy, massive, and cavernous limestone called the St. Louis limestone. It is of great thickness, homogeneous, stratified in heavy beds, with few shaly and friable members. Into this Green river is cut deep, with high precipitous banks, but the tributary streams on the surface are generally few and short. The drainage is chiefly underground through the labyrinthine caverns and crevices with which the limestone is honey-combed. The country is full of sink-holes, funnel-shaped depressions, into which the water flows and disappears. There are many valleys which have evidently been cut out by streams when the level of Green river was much higher than at present. As Green river cut deeper and deeper into the limestone, the tributary streams, having perhaps reached a level where the limestone was more subject to the action of water, left their former beds and sought an exit underground, through the seams and fissures which were gradually enlarged by the solvent action of the water until they form the numerous caves which are so characteristic of that region.

These in their turn were abandoned for other channels, as the river cut still deeper, and the most of them remain comparatively dry. The surface of the country thus underdrained, is fairly pitted with the sink-holes, into which the water runs, and from them gradually drains away through the limestone. Often the sink-holes become filled with clay and earth so that the water remains in them the whole year round. If at any time it is desired to drain them, it is easily accomplished by simply digging down through the clay till the limestone is reached, when the water sinks away at once. By reason of the great abundance of these sink-holes the topography is quite complex and varied, but the chief characteristics have been already stated; they are absence of long streams above ground, and abundance of sink-holes through which underground drainage is facilitated.

GEOLOGY.

We have represented in this region only the rocks of the carboniferous system, in the following divisions:

Carboniferous.	*Coal measures.*
Sub-carboniferous or Mountain Limestone.	*Chester Group.* *St. Louis Limestone.*

The description of these different formations will be given, beginning with the lowest of the region:

THE ST. LOUIS LIMESTONE.

This is the limestone known in the first series Kentucky Geological Reports as the cavernous member of the Sub-carboniferous Group. It is the limestone in which Mammoth Cave and all the similar caverns of that region have been formed. It is usually quite homogeneous in structure, very heavy-bedded, not very fossiliferous, occasionally somewhat earthy in appearance, and shows conchoidal fracture. The cavernous nature of this region is due wholly to the character of this limestone. It is so homogeneous and thick-bedded that such gigantic excavations as Mammoth Cave can be made in it without its crumbling or falling in, and thus filling them up.

The greatest thickness of this limestone which we have exposed within the field under discussion is about 230 feet, which is its height above Green river at Mammoth Cave.

In only a small portion of the field, covered by the accompanying map by Mr. Page, and that on the eastern part, does this limestone come to the surface not covered by other rocks.

The total thickness of this limestone in Kentucky has not been accurately determined. It is, however, much thicker than any exposure in this region, as has been proved by borings made in search of oil some years since. One of these wells, sunk on a branch of Dismal Creek, penetrated to a total depth of 804 feet, of which the last 524 feet is said to have been in solid limestone, and the boring was stopped without reaching the base of it. This gives us a greater thickness of this limestone below the drainage than we have exposed above. It is true that all of this limestone may not belong to the St. Louis Group; the limestone of the lower portion of the well may be a still lower member of the sub-carboniferous system, such as occur in other States, known as the Keokuk or Burlington limestone; but until they have been recognized in this State, it will be accurate enough to consider the whole thickness as belonging to the St. Louis.

THE CHESTER GROUP.

Between the massive St. Louis limestone and the sandstones and shales of the coal measures, there is a series of irregularly and frequently alternated limestones, sandstones, and shales, which mark a period of comparatively rapid and frequent geological changes; a progress toward the conditions which attended the formation of the coal measures, met by frequent returns to those which enable the deposition of a fine-grained crinoidal limestone, such as must have prevailed during the long period of the deposition of the St. Louis limestone.

From paleontological evidence, Mr. C. J. Norwood, Assistant in the Kentucky Survey, has identified this series with the Chester Group of the Illinois geologists. For the evidence upon which the identification is based, see his report.

These rocks immediately underlie the conglomerate at the base of the coal measures, and are exposed in nearly all this region.

Nolin river has its bed in these rocks for the whole distance covered by this report. Bear Creek runs in them from its head to some distance below the mouth of Sycamore Creek. Rock Creek likewise cuts its channel in them from head to mouth. All of the branches of Nolin river, of any size, in the region covered by Mr. Page's accompanying map, have their channels cut in the Chester rocks for the greater portion of their distances. They usually head in one of the sandstones of the coal measures; but the descent is rapid and steep until the Chester limestone is reached, when it becomes much more gentle and regular, and the fall is comparatively slight. The same is true of all the branches of Bear Creek, except Beaver Dam and Gulf Creeks, which, although touching the limestone once in the course of their descent, run in the conglomerate sandstone most of the way, as after these streams have once cut through to the limestone, a rapid dip to the west again carries it underground, and brings the conglomerate down to the bed of the creek once more.

The ridge forming the divide between the waters of Rough Creek and Nolin river and Bear Creek, and along which the Louisville, Paducah and Southwestern Railroad runs, is formed by Chester rocks, which here extend southward three or four miles before they are overlaid by coal measures.

The total thickness of the rocks of this group, as shown along the line of the Louisville, Paducah and Southwestern Railroad, is given by Mr. Norwood in his report as 262 feet. Mr. Norwood's general section of the Chester rocks, along the line of the railroad, as given in his report, is sufficiently accurate in its details for the northern part of the region covered by this report, but as we go south there is a marked change. The great thickness of marly shales, called the Leitchfield marls, and the numerous thin limestones, give place to heavy-bedded limestones and sandstones. This change will be alluded to more in detail hereafter. The thickness of the series, in the region covered by this report, does not vary much from that given by Mr. Norwood. It may be stated in round numbers at 250 feet.

The base of the Chester series, the equivalent of the Big Clifty sandstone of Mr. Norwood's report, is reached at but few places, except on the very eastern portion of the field, on Green river and its immediate branches.

Some wells, which have been already referred to, sunk in search of oil in this region a number of years since, penetrated through the entire thickness of this series and deep into the underlying St. Louis limestone. The records of some of these borings have fortunately been obtained for publication. One of these wells was sunk on a branch of Dismal Creek by Wm. C. Dodge, of Bowling Green, to whom we are indebted for the records. This well was started just below the level of the lowest coal of the neighborhood, and close to the top of the conglomerate, which is here only 25 feet thick.

The following is the record:

	No.		Thickness.	Total. depth.
Carboniferous 33 feet.	1	Clay	8	8
	2	Black sandstone (conglomerate S. S.) .	25	33
Chester series; total thickness 239 ft.	3	Shale	25	58
	4	Limestone	9	67
	5	Shale	15	82
	6	Limestone	34	116
	7	Shale	8	124
	8	Limestone	42	166
	9	"Mud vein" (probably shale).	17	183
	10	Limestone	20	203
	11	Black sandstone.	15	218
	12	"Sand and shale".	42	260
	13	Shale	20	280
St. Louis limestone 524 feet	14	Grey limestone (St. Louis limestone) . .	524	804

The above record is given as it was furnished for publication. The names in parentheses are added by the author of this report.

The horizon at which this well was begun is well ascertained to be the top of the conglomerate.

We have shown by the above section 239 feet of Chester rocks, reckoning the shale between the conglomerate and limestone, as belonging to this group. There is always a large margin to be allowed for error in measurements, and for mistakes in recognizing the material through which the drill is penetrating, as well as the precise point of change from one rock stratum to another, in considering sections obtained by drilling. It is a difficult matter, without the most careful study, to tell exactly what is the material being penetrated by the drill, for the reason that it is usually all finely pulverized, and there is a considerable admixture of material broken down from the sides of the well above by the drill-rods. Nevertheless, when these allowances are made, these records are of great value, and should always be kept. In the case of this well, there may be some errors in the record of the frequently changing strata of the Chester Group, but it is not probable there is any error in the total thickness, or in the measurement of the St. Louis limestone.

Other wells were sunk in this region on Rock Creek and on Brier Creek; but as yet we have been unable to obtain the records. Six wells, in all, were sunk in this region during the oil excitement. The following is the record of one of these sunk by the Kentucky Oil Company, on the Nolin Furnace tract, near Bear Creek, above the mouth of Decker Branch. The records were kindly furnished for publication by Col. Chas. E. Smith, of Indianapolis, under whose direction the well was sunk. The records were very carefully kept in detail, but in the following account they have been somewhat condensed and summarized. The exact geological level of the mouth of the well is not known, but it is evidently not far from the top of the Chester:

No.		Thickness.		Total depth.	
		Feet.	Inches.	Feet.	Inches.
1	Earth	9	. . .	9	. . .
2	Alternate bands of shale and limestone, mostly limestone	12	6	21	6
3	Shale, with thin bands of limestone, mostly shale	14	7	31	1
4	Hard limestone	38	6	74	7
5	Sandstone	20	3	94	10
6	Limestone	46	2	141	. . .
7	Black sandstone	9	. . .	150	. . .
8	"Mud" (probably soft clay shale)	6	. . .	156	. . .
9	"Slate" (probably hard shale)	2	6	158	6
10	Fine-grained sandstone	19	6	178	. . .
11	"Black mud" (probably soft black shale)	20	. . .	198	. . .
12	Black sandstone	6	. . .	204	. . .
13	"Slate rock"	10	. . .	214	. . .
14	Hard limestone (St. Louis limestone)	288	. . .	492	. . .

By the above record, which is, of course, subject to the before-mentioned liabilities of error, we have a thickness of 214 feet of Chester rocks, and 288 of St. Louis. We note here the beginning of the change in the upper part of the Chester to frequent thin limestones and shales, which are so characteristic of this formation further north.

The heavy sandstone, which is the base of the Chester series in the eastern part of this region, seems, as we go west, to disappear and give place to alternate thin sandstones and shales, the shales prevailing. This feature is shown quite conclusively by the two borings given above. Mr. Norwood also reports finding the same character to this rock in the western part of the coal field.

Further north and east, the sandstone occupies its proper place, growing thicker toward the east. Where the Louisville, Paducah and Southwestern Railroad crosses Big Clifty Creek, the thickness is stated by Mr. Norwood at 125 feet. At Mammoth Cave it is from 60 to 70 feet thick; but on descending Green river to the west it rapidly decreases to 40 or 50 feet, and even less. Near the head of Rock Creek it is 50 feet in thickness, but lower down it is only from 25 to 30.

In the region around Bee Spring, in Edmonson county, and for some six to ten miles north, the character of the Chester rocks differs materially from what it is in the neighborhood of Grayson Springs and Leitchfield. In the Bee Spring region, the series consists of three, and sometimes four limestones, with shales and sandstones between, the sandstone prevailing. The limestones, with the exception of the upper, are usually massive and homogeneous, ranging from 15 to 45 feet in thickness, and occasionally thicker. The upper is usually only from two to ten feet in thickness, and is often in several thin bands in shale. The section of the well last given shows this feature very characteristically. This limestone is usually more fossiliferous than the others. Where it is split up into several thin bands, the aggregate thickness is usually greater than when it consists of a single layer.

The two wells, the records of which have just been given, show typical sections of the Chester rocks of this region, as just described.

Further north, around Grayson Springs and Leitchfield, in place of the heavy limestones at the upper part of this series, we have a very changeable series of shales, marls, or marly shales, thin shaly sandstones, and limestones. At Cedar Knob, near Grayson Springs, a thickness of 115 feet of these rocks is seen, and the most of the shales and sandstones are calcareous. The limestone here, which is persistent, is probably the lowest one of the series. It occurs on Bear Creek, near Grayson Springs, and below. It is seen, at the Chapel, 40 feet in thickness. It dips, however, rapidly down stream, and is overlaid by the shales already referred to, which take the place, in this region, of the heavy limestones further south. Above Grayson Springs it rises rapidly.

In the northern and eastern portions of this region the Chester rocks are peculiarly subject to faults. There are almost innumerable small faults of from 10 to 50 feet vertical distance. They are most abundant where the Chester rocks are not overlaid by the coal measures, but in many places they are seen reaching up through the conglomerate. They are so numerous and irregular—not, so far as we can at present see, following any general direction, any line of uplift or down-throw—that they are often very perplexing, and render the taking of accurate sections quite difficult. They are usually local, and, in most cases, seem to be down-throws.

The Grayson Springs issue near a fault of this kind which extends through the lower sandstone and limestone of the Chester Group. The line of this fault undoubtedly determines the position of these medicinal springs which are here in so great number: the waters, from a depth, probably following the line of the fault underground, as they find it the channel of easiest ascent. The number of springs here is great and their value high. For analyses of the waters from these springs, see the report of Dr. Peter.

DIP OF THE CHESTER ROCKS.

The region covered by this report is really a projecting tongue of the coal measures in the form of a basin or trough, in which the rocks have a general dip to the west, while there is also a modified dip from north and south toward the center of the basin or trough. The Chester rocks underlying the coal measures rise to the surface both to the north and south. The northern edge of this basin is the ridge already referred to, along which the Louisville, Paducah and Southwestern Railroad runs. Chester rocks are the only ones exposed for from two to three miles south, when they are overlaid by the coal-measure rocks. They are seen, however, still dipping south and west, on all the streams until Dismal Creek is reached, when the dip begins to change and they gradually rise toward the south, coming to the surface again on the south side of Green river, beyond the field of the map. The rise southward from Dismal Creek cannot be traced accurately in many places, as the upper part of this series is cut away by the heavy conglomerate. We only know that the rise does take place, as we find the rocks much higher to the south, even when the heavy conglomerate overlies them.

By reference to the accompanying cross-section, No. 2, running nearly south from Grayson Springs Station to Green river, the above mentioned facts in regard to the dip will be readily seen. The lower limestone of the series is 30 feet below the railroad at the station, which, by Mr. Page's levels, is 313 feet above low water in Green river, at Brownsville. The rocks descend to the south by a series of small faults until we find the top of the same limestone about 20 feet above Bear Creek, at Grayson Springs, or 150 feet above Green river. This descent is in two and one half miles distance. The top of Cedar Knob, near Grayson Springs, is 330 feet above Green river, with marly shales and limestones of the Chester Group extending to the very top. The descent is quite rapid from this point at first, something near 90 feet per mile, and then more gentle, until at the crossing of one of the branches of Dismal Creek, near Berry's Lick, where the upper Chester rocks reach the lowest point on this section, 110 feet above Green river. The top of a limestone is seen lower than this on Pigeon Creek; but this is where the upper members are missing, having probably been cut away at the time of the deposition of the heavy conglomerate. Near Brownsville we have the highest Chester limestone exposed, 160 feet above Green river. As already stated, the faults seem most abundant on the northern and eastern borders of the region under discussion. In the central region, between Nolin and Bear Creek, faults seem to be very rare. Irregularities in the upper surface of these rocks are, however, very great, especially where the heavy conglomerate rests upon it. These irregularities are well shown along Green river, above and below the mouth of Bear Creek. One half mile above the mouth of that creek the limestone extends 50 feet above the level of the river. At Bear Creek the conglomerate is seen in the river banks, and the limestone near the level of low water. Below Bear Creek, Mr. J. R. Procter reports the limestone at Indian Fort as seen, 40 feet above Green river, while one fourth mile below, it disappears below the drainage; the top of the conglomerate at the same time descending from 235 feet to 125 feet above the river, thus showing undulations equal to or greater than those in the limestone.

In the northern part of this region there are numerous beds of marly shale, which are quite conspicuous, in their frequent outcrop, on account of their bright colors. They range from a dark red to bright yellowish-green. As yet, they have been only occasionally used, in small quantities, for paints. The colors which can be obtained by the use of these earths are fine, and they are capable of yielding an indefinitely large supply. Analyses of these marly shales, from a number of places, by Dr. Peter and Mr. Talbutt, give between four and five per cent. of potash. They would, therefore, if the potash can be rendered soluble, be of the greatest value as fertilizers, especially for exhausted tobacco lands. For the complete analyses, and further information in regard to the value of this material, see the report of Dr. Peter.

THE CHESTER COAL.

At many points near the edge of this region, on Rock Creek, on Nolin river and some of its branches, as high as Roundstone Creek, on Dog Creek and Cub Run, and on Green river, there is found in the rocks of the Chester series a thin coal. This coal has been already referred to in the report of S. S. Lyon, fourth volume, first series Kentucky Geological Reports, as having been found at the head of Rock Creek. It has been observed at so many points that it may be considered as of more than local occurrence. In fact, it seems to be one of the best marked and most trustworthy members of the series. It occurs at the base of a heavy limestone, which is probably the lowest of the series. It has not been seen by the writer of a greater thickness than three inches, hence it is of no economical importance, as it is not of workable thickness. It has served to delude some persons, in times past, into the belief that they might find coal in quantity to pay for working in places where only the Chester rocks occur; but not much labor has been wasted in the search. It usually has from a few inches to two feet of shale between it and the limestone, and rests upon a thin band of fire-clay. The coal is usually quite pyritous and somewhat slaty. The overlying shale is pyritous also, containing casts of stigmariæ in pyrites. The shale contains abundant impressions of various coal-measure plants, the leaves or spines of *Lepidodendron*, *Sphenophyllum cordiates*, &c. It usually immediately overlies a thin shaly sandstone or marly shale, but is not far from the top of the Big Clifty sandstone. The following section, at Mr. Wise's, on the south bank of Green river, near Brownsville, shows the usual association of the coal:

Limestone, probably 35 feet in all, seen only	25	feet.	
Sandstone (partly covered)	40	“	
Limestone	23	“	
Shale	1½	“	
Coal	¼	“	
Fire-clay			1 inch.
Clay shale	3	“	
Sandy shale	1½	“	
Covered	8	“	

Top of sandstone about 30 feet above Green river.

The base of the limestone above the coal is at high-water mark of Green river. The above section is a typical one of the many which have been obtained in which this coal shows. There is little doubt that this limestone, immediately above the coal, is the lowest one of the series, and that the sandstone, at the base of the section, is one of the top layers of the Big Clifty sandstone.

Although of no economical importance, the occurrence of this coal is of much scientific interest, in that it marks the beginning of true coal formation at a period long anterior to the deposition of the true coal measures. The geological changes which its occurrence indicates are also interesting. After the long period of quiet submersion, during which the great thickness of the St. Louis limestone was formed, an era of disturbed waters and rushing currents was begun, and the coarse, massive sandstone at the base of the Chester series was deposited. This rock bears, at many places, a striking resemblance to the conglomerate at the base of the true coal measures, although it has never been found carrying pebbles. As the waters became less disturbed the sandstone grew finer and more shaly. merging at last into a sandy shale, which, as more silt and less sand were deposited, became a fine clay shale, which formed the soil for the plants afterwards converted into coal. Immediately following the deposition of the slight thickness of shale above the coal, a marked and sudden change occurred; a submersion took place in waters in which the abundant crinoids once more began their work of limestone making. The formation of coal, thus interrupted, was not resumed until a thickness of many feet of alternated limestones, shales, and sandstones had been deposited.

THE COAL MEASURES.

As already stated, this region is in reality a basin or trough, forming a projecting tongue of the coal measures, surrounded on three sides by the sub-carboniferous rocks. On the eastern border, this tongue of coal-measure rocks is split in two by the Nolin river, and we have one part capping the ridge between

Nolin river and the branches of Rock and Sinking Creeks, while the other forms the divide between the waters of Nolin and Green rivers, extending further to the east, although the eastern limit of the coal itself is very nearly the same in both.

The boundary of the coal-measure rocks within the field covered by the accompanying map by Mr. Page, is about as follows: beginning at a point on the Leitchfield and Brownsville road, about three miles from Leitchfield, it crosses to Bear Creek, below the mouth of Cedar Lick Branch. From here it continues in an easterly course close to, and on the south side of, Cedar Lick Branch to its head, on the divide between the waters of Bear and Rock Creeks. It then turns a little to the north, and follows the divide between Bear and Rock Creeks, as far north as Grayson Springs. Turning east until Rock Creek is nearly reached, and then south again, it crosses that stream below the mouth of Grindstone Branch, and turns once more in an easterly direction. It continues this course for several miles, once crossing to the north of Grindstone Branch, but for the most part following the ridge between that branch and the Hunting Fork of Rock Creek, and after it passes the heads of these streams, between Sinking Creek and Barton and Laurel Runs. The very eastern extension of it on this outlier, is on a high hill called the "Devil's Backbone," just east of Laurel Run, which is capped with about 50 feet of coal-measure rocks.

Turning a little west of south, the line pursues the divide between Nolin river and the waters of Rock Creek, crosses Rock Creek near its mouth, and Nolin river near the mouth of Dog Creek. It then follows in a southerly course, on the south side of Dog Creek, for about two miles, when it once more turns to the east, along the divide between the branches of Dog Creek and Nolin river, and continues in that direction until it passes beyond the field of the map. The coal-measure conglomerate forms the ridge continuously on the divide between the waters of Nolin and Green rivers for several miles beyond the field of the map, and then occurs in disconnected outlying patches nearly to Munfordville. The southern boundary of this projection enters the field of the map at the head of Cub Run. Occasional detached outliers extend to the south, between Cub Run and Ugly Creek, even across Green river; but the boundary of the main body runs east, across the head of Ugly Creek from Cub Run, then turns southeast, crosses Buffalo Creek diagonally with its course, and pursues nearly the same direction until it reaches and crosses Green river below the mouth of Buffalo Creek, passing out of the field of the present report.

The limits of, and the area covered by, the coal-measure rocks, will be much more readily understood by referring to the accompanying geological map, in which the different formations are colored so as to show the area covered by each.

Within the above described limits there is a considerable area, which is described as covered by coal-measure rocks, where no coal will be found. The conglomerate, which is here the first of the coal-measure rocks, covers the surface, but the coal which lies above it, and the upper part of the rock itself, have been worn away by long-continued exposure. It is for this reason that the map was not extended to the eastern limits of the area covered by the conglomerate. Coal may possibly be found on the top of some of the conglomerate-capped hills, beyond the edge of the map; but the probabilities are strongly against it, and if found, it will be in extremely small areas—mere patches as it were.

In the outlier north of Nolin river,coal has been found as far east as the head of Barton's Run, and will probably be found still further east, if sought for in the right place, although it probably does not extend as far as the indicated eastern limit of coal-measure rocks. Reports were heard in regard to coal as far east as the mouth of Roundstone Creek, on Nolin river; but on examination, it proved to be the Chester coal already described.

Between Nolin and Green rivers, coal has been found on Dog Creek, on Longfall, between Brier and Bylew Creeks, and between Bylew and Buffalo Creeks; but it has not been found further east than the heads of these streams, nor is it probable it will be. The conglomerate forms the ridge at the head of these streams, and for a long distance east, and it is so near the surface, that it is probable the coal has been all removed. This is also the case toward Green river, although in the main ridges the conglomerate is covered, so that there is a possibility of finding the coal at many places.

Reference has been made, in the discussion of the topographical features of this region, to two heavy sandstones, which are the prominent agents in the determination of the topography of the coal field. These two sandstones are the most prominent features in the geological structure, and where they prevail a very different succession of rocks is found. They are: the conglomerate at the base of the coal measures, and a heavy, massive, rarely conglomeratic sandstone, which has been called by Lyon, in the fourth volume, first series Kentucky Geological Reports, the fifth sandstone of the millstone grit series—a series of rocks beginning with the St. Louis limestone, which he termed "the cavernous member of the sub-carboniferous limestone," and extending up into the coal measures. It includes, therefore, what is now identified by Mr. Norwood as the Chester series, and the lower portion of the coal measures. This sandstone, which he termed the fifth sandstone, is in this vicinity not the fifth sandstone above the St. Louis limestone, but the fourth. The name, therefore, is for this region incorrect, and will be discarded. In its place it will be called the Bee Spring sandstone, from the Bee Spring in Edmonson county, where it is well shown in its characteristic features.

The principal problems in the geology of this region are in connection with the occurrence of these two sandstones; and for this reason, and to lead to a correct understanding of the stratigraphy, a description will be here given of their character and distribution.

THE CONGLOMERATE.

The first of these sandstones, the conglomerate proper, in the northern part of this region, is usually thin, and often wanting altogether. In the northwestern portion of the field under discussion, on upper Bear Creek and its branches, it is either absent altogether, or present as a coarse, non-conglomeratic sandstone. Where found, it is usually only from 15 to 25 feet thick, though occasionally a little thicker. This is its usual thickness north of Nolin river and east of Rock Creek, and it is well marked by the pebbles it carries. Here, more than in any other part of this region, the conglomerate and the coal-measure rocks above are affected by the faults, which have been referred to as so frequent, in the Chester rocks. South of Nolin river, which is here running nearly west, the conglomerate thickens rapidly. West of Rock Creek, and between Nolin river and Bear Creek, for about fifteen miles south, the conglomerate is not seen, at any place, more than 50 feet in thickness, while it is usually about 25. It is also found of about this thickness east of Nolin river, between Brier, Longfall, and Dog Creeks, not extending, however, near to the heads of any of these streams. The limit of the area, where the conglomerate is of this unimportant thickness, is a line somewhat irregular and broken, extending from Bear Creek, above the mouth of Beaver Dam Creek, in a general east-northeast course, crossing Nolin river at the mouth of Dismal Creek, then across Brier, Longfall, and Dog Creeks, until it passes beyond the field of the map. From this line south to Green river, and beyond, the conglomerate is of great thickness, ranging from 60 to 190 feet. This thickening gives us a very different geological section north and south of the line. It is often very sudden in its occurrence, and seems to be effected by the cutting away of several of the underlying Chester rocks. This is finely shown, in one case, near the mouth of Dismal Creek. Here, upon the west side of Nolin river, is a section exposed, showing two sandstones and two limestones, as follows:

Pebbly iron ore, thickness not seen.	
Covered	3 feet.
Conglomerate sandstone	20 "
Covered.	15 "
Sandstone	10 "
Covered	15 "

Limestone	25 feet.
Covered	10 "
Sandstone (not conglomeratic)	25 "
Limestone, not seen at this place, but exposed below	15 "
Covered	20 "
Level of Nolin river.	

On the opposite side of Nolin river, in full view, and not more than one fourth of a mile distant, is exposed the well-known Dismal Rock. This is a vertical cliff of conglomerate sandstone, resting upon the lower limestone of the section just given. The total height, as measured by Mr. Page, is 165 feet, of which the conglomerate forms 130 feet.

The section is as follows:

Conglomerate sandstone	130 feet.
Limestone	35 "
Level of Nolin river.	

The top of this rock, as nearly as can be determined with a hand level, is on a level with the top of the upper sandstone of the section just given. We thus see that the currents which have deposited this rock, have cut away about one hundred feet of the Chester rocks, and deposited in their place the heavy conglomerate sandstone.

This sudden thickening is well shown by cross-section No. 4, from Nolin river to Bear Creek, along Dismal Creek, and down Mill Branch. The thickening at this place, from 25 to 130 feet in one fourth of a mile, is all downwards. At other places it seems to be accompanied by a rise in the top of the conglomerate, as well as by an increase in depth.

A large portion of this region is underlaid by this conglomerate, where it is at its greatest thickness. It forms a great irregular mass, with the line of its greatest thickness extending in a course nearly east-northeast. It forms the divide between the waters of Nolin and Green rivers, on the very eastern border of the region covered by Mr. Page's map. Along this ridge it is very prominent, presenting many bold escarpments, and ranging from 80 to 130 feet in thickness. It does not, however, until within the field of the map, extend in any great width to the north or south. Cane Run, Cub Run, Ugly Creek, and other branches, head in the thick conglomerate, but soon pass through it, and have their valleys altogether in the Chester and St. Louis rocks. As already stated, it extends to the southwest, and crosses Green river below the mouth of Buffalo Creek. Green river cuts its way through it for some distance west of the mouth of Bear Creek. Its limit to the south of Green river has not yet been accurately determined.

From the north line of the coal measures, where the conglomerate is first seen, to the center of its greatest thickness, there is an increase from north to south from 25 to 180 feet. On the southern edge it disappears abruptly, while from 75 to 130 feet thick. There is some thinning in that direction, but it is slight in comparison with that to the north. The greatest thickness known is on the upper part of Dog Creek and its branches. Here it is found as high as 180 feet in thickness. On Piney Branch of Dog Creek there is a single cliff exposure of this sandstone called the "Buzzard Roost," where 160 feet is seen in one face, and 175 feet is the total thickness. The stream here has cut away the base of the sandstone, and formed a rock house of considerable depth and unusual height. The stream here has not cut to the bottom of the sandstone, although the Chester limestone is seen a short distance below. There is in the valley of this branch either a remarkable and rapid dip to the north, from the head of Buffalo and Ugly Creeks, or there is a total thickness of the conglomerate of nearly 275 feet. In less than two miles, going north from the head of Ugly Creek, the distance from the top of the conglomerate on the ridge to the base in the valley is 275 feet. There is, in this distance, room for considerable dip, which probably accounts for the apparent great thickness. The conglomerate has not been found at any point, where the observation was free from possibility of error, of more than 180 feet thickness. Dog Creek cuts its way through the thick conglomerate for nearly its whole length, only emerging from it within the last two miles.

Of the streams flowing into Nolin river, Pigeon and Pine, Bylew, First and Second Creeks cut through it from head to mouth, Beaver Dam and Gulf Creeks, and all their branches, of the tributaries of Bear Creek, do likewise, as also Indian

Creek and the other streams flowing directly into Green river from the north, between Nolin river and Bear Creek.

Bylew Creek cuts longitudinally through the very thickest of the conglomerate, and the result is, that, in its tremendous cliffs and narrow gorge-like valley, as well as the magnificent views which it presents, it is unequaled in this region.

In all the region covered by this thick sandstone, exposures of from 80 to 125 feet in one face are frequent. Its outline is by no means regular, but varies greatly, being full of indentations and projections, so that the direction already given as the line of the axis of greatest thickness is to be understood as approximate only.

The rock has evidently been deposited by very swift-moving currents of water. This is proved by the character of the rock itself, which, where the thickening is rapid and great, as on Nolin river, is composed chiefly of large quartz pebbles, many of them larger than a hen's egg, with barely enough sand to cement them together.

These masses of pebbles have only been found near the bottom of the sandstone, where it is at nearly its maximum thickness, and near the border. The pebbles gradually diminish in frequency as we approach the top, where they usually are found in thin, irregular layers, with a considerable thickness of sandstone between, which is almost or entirely free from pebbles. There is also a gradual diminution in the number of pebbles from the east toward the west and north. At many places on Bear Creek, where the sandstone is still of great thickness, it is hardly conglomeratic at all. It is also noticeable that where the conglomerate is thin, the pebbles are not nearly so abundant. As we approach the northwestern portion of this region the pebbles disappear almost entirely, and the sandstone itself is erratic, sometimes present and sometimes not, and, where present, is recognzied only by its position. I am informed by Mr. Norwood that still further west, along the line of the Louisville, Paducah and Southwestern Railroad, there is no true conglomerate found at the base of the coal measures on the eastern border of the coal field.

This coarse, pebbly sandstone can only have been deposited by very swift currents of water, and only such were energetic enough to wear away the rocks which the conglomerate replaces. From the character of the rock these seem to have acted with the greatest force from the east, or, more probably, from the southeast, as we find the conglomerate thinning, and finally disappearing to the north, while it changes character to the west, while still retaining a considerable thickness. West of Bear Creek there are indications, although the region has not been examined in sufficient detail to make the assertion positively, that the sandstone, instead of dipping beneath the surface entirely, gives place to a great thickness of shales, which occupy nearly the same geological position. Should this, on more thorough examination, prove to be the case, it will furnish additional strongly corroborative evidence of the statements just made in regard to the direction of the currents which deposited the sandstone.

Further than this, in the eastern portion of this region, between Nolin and Green rivers, at the heads of Bylew, Brier, and Longfall Creeks, there is a second strongly marked conglomerate, at a distance of about 30 feet above the lower, with a coal bed between. Further south and southeast the two conglomerates seem to unite. To the northwest the upper conglomerate changes character, becomes rarely conglomeratic, is thin-bedded and shaly at places, and considerably thicker. It seems here to be identical with the Bee Spring sandstone. Between Brier and Bylew Creeks it is full of pebbles, but they rapidly disappear towards Nolin river. This apparent identity is shown in cross-section No. 1, from Leitchfield to Mammoth Cave.

The occurrence of this second conglomerate in the eastern part of this region above a coal, indicates a long-continued action of rapid currents from this direction, continued and repeated after the elevation and change of conditions in the other portion of this region, which accompanied the deposition of the coal. It is worthy of notice that this sandstone changes its character to the northwest much more rapidly than the main conglomerate.

The pebbles of the conglomerate are of quartz, usually white, though occasionally a few are found of rose color or jaspery quartz, but never of any other material.

THE BEE SPRING SANDSTONE.

This sandstone, for all that region north of the line which has been given as the northern limit of the heavy conglomerate, is by far the most prominent member of the geological column. It is most extensively developed between Nolin river and Bear Creek, where it shows abundant exposures of from 50 to 60 feet. It lies near the top of the ridge, and has served to form it into a comparatively even, gently rolling table land. Near the northern edge of the coal-measure rocks this sandstone has changed its position, become thinner, and is difficult of identification. There is also here a change in the position of the coals, as will be shown further on. It is not until about five miles south of the extreme northern border that this sandstone reaches its maximum thickness. It then extends for about seven or eight miles south, varying very little in its thickness until south of Dismal Creek, and on the head streams of the different branches of Sycamore Creek, when it becomes thin, rises rapidly to the south, and finally disappears. The position and character of the sandstone here are somewhat obscure. It is usually covered, and very rarely seen outcropping in position. It is certain that it thins rapidly when it comes to overlie the heavy conglomerate. As the conglomerate thickens this sandstone thins. South of Beaver Dam and Pigeon Creeks it has not been recognized, nor is there any indication of its presence shown by the slopes of the hills.

The thickening of the conglomerate and the disappearance of the Bee Spring sandstone take place within a comparatively short distance—about two miles. The character of the change in the conglomerate can be determined, as it is frequent in outcrop; but all is obscure in the change and final disappearance of the Bee Spring sandstone.

This sandstone north of Bee Spring is usually quite coarse, and, in a few instances, contains small pebbles; but these are rare. It is remarkable for the great number of springs which issue from its base. Most of the streams head in this sandstone, and at almost every branch there is found a spring issuing from its base. Many of these springs are strongly chalybeate.

The sandstone is here coarse at the bottom and somewhat shaly at top, so that the top is frequently covered. When pebbles occur, they are usually small, and lie between the layers of the sandstone.

North of Nolin river and east of Rock Creek this sandstone changes character somewhat, becoming thin-bedded and shaly. It is, therefore, not nearly so conspicuous. Exposures of it are comparatively scarce; but its presence is indicated by the topography. It forms the divide between Nolin river and the branches of Rock Creek, where the top of it is from 325 to 400 feet above Nolin river, rising towards the east.

South and east of Nolin river, between that stream and the line of the heavy conglomerate already given, there is a triangular area, including the field crossed by Brier, Longfall, and Dog Creeks, in the lower portion of their descent, where this sandstone is found, sometimes shaly and sometimes conglomeratic. As shown by cross-section No. 1, from Mammoth Cave to Leitchfield, this sandstone here occupies the same position as the upper conglomerate, and is doubtless identical with it, although north of Brier Creek it is much thicker. It is, however, found conglomeratic between Brier Creek and Mt. Vernon Mill, on Nolin river.

GENERAL SECTION.

As shown in the description of these two great sand-rocks, there are sudden and great changes in the order and thickness of the various rocks of this region, so that for the whole region, a general section cannot be given which will be of any service in accurately indicating the order and thickness of all the rocks. For a large portion of the region, however, in the already described field, where the Bee Spring sandstone has its best and most characteristic development, a general section can be given, which will show with considerable accuracy the order and thickness of the various rocks, as follows:

General section of the coal-measure rocks east of Bear Creek, and north of Beaver Dam and Pigeon Creeks, Edmonson and Grayson counties, Kentucky:

1.	Clay shale, with nodules of iron ore	35	to 35	feet
2.	Iron ore, reported thickness	1½	to 1½	"
3.	Clay shale	30	to 30	"
4.	Iron ore	2	to 3½	"
5.	Space, probably filled with clay shale	0	to 20	"
6.	Clay shale	15	to 15	"
7.	Coal	⅔	to ⅔	"
8.	Coarse sandstone, "Bee Spring S. S."	20	to 60	"
9.	Sandy clay shale	0	to 20	"
10.	Coal	1	to 2	"
11.	Shaly S. S. changing to shale.	15	to 20	"
12.	Space, probably filled with clay shale	15	to 20	"
13.	Main Nolin coal	2	to 3⅓	"
14.	Fire-clay and shale	3	to 10	"
15.	Conglomerate sandstone	15	to 25	"
16.	Shale	0	to 25	"
	Top of Chester limestone.			

This section applies very well for most of the region between Nolin river and Bear Creek; also for the region between Bear and Rock Creeks, except at the very edge of the coal-measure rocks, where there is some thinning out. It will also answer for a portion of the country east and south of Nolin river.

For the region of the heavy conglomerate it is difficult to give a general section, for the reason that the rocks above are almost always covered. There is rarely more than 100 feet thickness of material overlying the thick conglomerate, although at a few of the highest points it reaches 150 feet. As evidenced by the slopes, this is mostly shale or shaly sandstone. These are also the most prevalent in wasted outcrops, on the hillsides. A complete section of the rocks above the heavy conglomerate has not been obtained anywhere in this region. The nearest approach to this was at Stevens' coal bank, on the west bank of Bear Creek. This section was partly made from statements of Mr. Stevens in regard to the rock passed through in sinking a trial shaft near his entry.

SECTION AT STEVENS' COAL BANK.

Top of hill.		
Covered slope, probably sandstone	35	feet.
Iron ore	½	"
Shale	3	"
Coal (reported)	1⅙	"
Covered	5	"
Sandstone	20	"
Shale	40	"
Sandstone	4	"
Covered (probably shale)	18	"
Coal	3	"
Fire-clay	2½	"
Sandstone (conglomerate)	50	"
Bed of Bear Creek.		

This section shows more sandstone, than is indicated at most places, above the conglomerate.

Between Nolin river and Rock Creek, and in the corresponding country across Nolin, below Dog Creek, the same trouble is experienced in obtaining a complete section, owing to the scarcity of exposures. The conglomerate, here thin, and the Bee Spring sandstone, usually shaly, are here pretty well defined, as also the Nolin coal, resting immediately upon the conglomerate; but the space up to the Bee Spring sandstone is uniformly covered, and it is still a matter of uncertainty whether the coal, which at other places is just below that sandstone, is present or not.

Near the northern limit of the coal-measure rocks, changes are again so frequent that a general section cannot be given, that will be of any service. The Bee Spring sandstone here is thin and shaly when present; as well as the conglomerate, it is difficult of identification. At places the sandstone, which seems to represent the conglomerate, is close down to the Chester limestone, with not more than two or three feet of marly shale intervening; while at other places, within a short distance, it is fifteen feet above the limestone, and a coal occurs between.

There is a well-marked rise in the rocks, from both north and south, towards the head of Canoloway Creek and Long Branch of Bear Creek. This is well shown by cross-section No. 2, south from Grayson Springs Station, and No. 1, from Mammoth Cave to Leitchfield. From here the rocks dip rapidly north for about two miles, and then rise again rapidly, in conformity with the rise of the Chester rocks. The changes in the character of the rocks, here, are somewhat obscure, as is also the equivalency of the coals. If the sandstone last described be the conglomerate, the lowest coal is a sub-conglomerate, without doubt. If, on the other hand, the lower conglomerate has disappeared, and the sandstone above is the equivalent of the Bee Spring sandstone, we have a section which does not differ so greatly from that further south.

The following will serve as an instance of the rapid changes in the rocks of this region: On Miller's Fork of Bear Creek, at the Gravelly Lick, a coal is seen which is only eight feet above the limestone; a little above, the sandstone, 40 feet thick, is seen, with a covered space of 15 feet between it and the limestone, in which space the coal will undoubtedly be found. On the next branch below, to the west, the sandstone is found close down to the limestone, with only about three feet thickness of shale between. About one mile further west, just across Bear Creek, in the Leitchfield road, the coal is exposed about 12 feet above the limestone. Above the coal is a space of 40 feet, mostly filled with shale, and then a sandstone 26 feet thick. In this short distance the coal disappears and reappears, while a thickness of 40 feet of shale comes in below the sandstone.

A fine section is here exposed which shows quite characteristically the many shales, marly shales, and shaly sandstones of the upper Chester Group.

The section is as follows:

Coarse friable sandstone	26	feet.
Covered (probably sandstone)	3	"
Clay shale	8	"
Covered (probably shale)	7	"
Clay shale	22	"
Coal	1½	"
Fire-clay	1	"
Covered	12	"
Wasted sandstone	3	"
Limestone	2¼	"
Shale	1	"
Covered (probably marly shale)	6	"
Green and red marly shale	4	"
Covered	7	"
Greenish shale	3	"
Amount carried forward	106¾	

Amount brought forward	106¾
Shaly sandstone	2 feet.
Whitish shale	1 "
Covered (probably shale)	16½ "
Green marly shale	5½ "
Yellow crumbling limestone	½ "
Green shale	3 "
Greenish shaly sandstone	2 "
Total thickness	137¼ "

COAL.

By reference to the general section for the region between Bear Creek and Nolin river, north of Beaver Dam and Pigeon Creeks, it will be seen that there are here three coals. The first of these rests close upon the lower conglomerate; the second underlies the Bee Spring sandstone; and the third rests immediately upon it. Of these, the first is the only one which has been found of workable thickness over any considerable area. The second is reported as 30 inches thick at some places; but it has not been seen by the writer of this of over 18 inches thickness, and in most places it is not more than 12 inches. The third coal has not been found of workable thickness; it is usually only from 8 to 12 inches. The first of these coals was called by Dr. D. D. Owen, in the first volume, first series, Kentucky Geological Reports, the Main Nolin coal, a name which, until the numbering of the coals in the western coal field is finally determined upon, will be retained here. It is the equivalent of Coal L of Mr. Norwood's section along the line of the Louisville, Paducah and Southwestern Railroad. These three coals are quite persistent over all that area where the Bee Spring sandstone is characteristically developed.

The normal distance of the Nolin coal above the Chester limestone is from 20 to 30 feet. The second coal is 40 feet above this, and the third 70 feet above the second. These distances are subject to some slight variation, but within the above limited area this is not great. This section holds good to within three or four miles of the northern edge of the coal-measure rocks, where the changes in the general stratification, which have been already referred to, affect also the position of the coal beds.

We have not here, in any one section, more than two coals exposed, and as we approach the border of the coal-measure rocks but one is found. The following section, on Long Branch of Bear Creek, near Eli Decker's, will serve to show the position of two coals:

Coal	1	foot.
Covered	5	feet.
Sandstone, hard and solid	4	"
Sandstone, shaly	6	"
Sandstone, hard	4	"
Covered	13	"
Clay shale	5	"
Carbonate iron ore	½	"
Clay shale	7	"
Coal, thickness not seen.		
Covered	5	"
Coarse sandstone	35	"
Covered	15	"
Top of Chester limestone.		

Between the base of the sandstone and the limestone there is found, at another locality on this branch, a marly shale belonging to the Chester Group. On the next branch north, called Miller's Fork, there is a coal between this sandstone and limestone.

The changes which take place in the rocks here are well shown by cross-section No. 2, from Grayson Springs Station to Green river. East of this region, on Rock Creek, and beyond, it is also difficult to give a general section, as good exposures are comparatively rare, and there are frequent changes in the character of the rocks. But one coal is here known near the border of the coal measures. This, between Rock and Bear Creeks, is usually only from 10 to 20 feet above the Chester limestone. It has been opened for local blacksmiths' use at Thomas Higdon's, on Cedar Lick Branch of Bear Creek; at John Skagg's, on Dice Branch of Rock Creek; at Lec. Higdon's, on Pearson's Branch of Rock Creek; and at numerous other places. The coal frequently carries a bed of iron ore resting upon it. The ore is a very fair quality of limonite, changing to carbonate as it is followed into the hill, and is from five to eight inches in thickness. The coal itself is from 20 to 27 inches thick, and of very good quality.

East of Rock Creek, in the corner between that stream and Nolin river, there has been but one coal recognized. This is usually 20 to 30 feet above the limestone, resting almost immediately upon the conglomerate, with only the intervention of a few feet of shale and fire-clay. At one locality, a place was seen where another coal is said to have been formerly exposed, but it is now covered, and there is no evidence of its existence. If there be a coal here, it is about 50 feet above the first. The rocks are so generally covered that it has been seen at no other place.

The coal resting upon the conglomerate has been very much disturbed, in the ridge between Rock Creek and Nolin, by frequent faults, which are upon both sides of the ridge. The faults seem to be a series of down-throws or step faults, which follow around the main ridge. They are usually of small vertical extent, hardly ever over 50 feet; but there are a number of them, so that we find the coal at very different heights, dipping, apparently, very rapidly towards both streams, but really carried down by the faults. The greatest thickness of this coal seen here, at any place, was 28 inches; but it is reported, at other places, as three feet and over. The Bee Spring sandstone caps the ridge here, and it is probable the coal, close below it, will be found, on searching in the proper place.

Across Nolin river but one coal has been found. This is the equivalent of the Main Nolin coal, with the sandstone above changed to a conglomerate, and the distance between considerably lessened. Near Mt. Vernon Mills, the Bee Spring sandstone is developed very characteristically, about 30 feet above the coal, which is here exposed nearly two feet thick, and the bottom of the coal still covered. Resting upon the coal is an eight-inch bed of iron ore of good quality.

On Long Fall Creek, at the Old Thompson bank, the coal is very near the top of the lower conglomerate; but the overlying rocks are so covered that it is impossible to determine them exactly. Higher up on the creek, the upper conglomerate is found above the level of the coal. The coal here was covered at time of examination, so that its full thickness was not seen, but it is reported to be something over three feet.

As shown by cross-section No. 2, from Mammoth Cave to Leitchfield, the coal rises rapidly toward the southeast. Between Brier and Bylew Creeks, it is found overlying about 70 feet of conglomerate, and close under a second conglomerate 35 feet thick. The coal is near the overlying sandstone, with a covered space of 25 feet between it and the lower. This is the most southern exposure of this coal with the overlying conglomerate. On the head of Bylew Creek, the conglomerate consists of two members, with a covered space between, in which the coal belongs; further south and east, the conglomerate is seen solid from 100 to 180 feet thick, without division. The coal occurs at the head of Mill Branch of Bylew Creek, some distance south of the main stream, resting immediately upon the heavy conglomerate, and with no evidence of the existence of a higher one. There is here an iron ore above the coal, but the thickness of neither ore nor coal was seen. The coal here has risen about 60 feet from where last seen, on the head of Brier Creek. Further west, at the head of Piney Branch of Nolin, the coal is seen, apparently thin, resting close upon the conglomerate, which is 140 feet thick. No coal, except the thin sub-limestone coal, has been found further east, along the main ridge between Nolin and Green rivers, than the head of Brier and Bylew Creeks; nor is it probable that there will be, in any quantity, as the conglomerate is very close to the surface, sometimes not covered at all, and hardly ever with more than 30 feet of overlying material. If the coal is found, it will only be on the isolated hills where there is enough overlying material to protect it.

North of the main dividing ridge, between Dog Creek and Nolin river, coal is found further east than on the main ridge, as the conglomerate is somewhat lower, and there is a greater thickness of overlying material. It will not probably be found, however, a great distance east of Dog Creek, as the rocks rise rapidly in that direction, bringing the conglomerate close to the surface, once more. South of Bylew Creek, between Nolin and Green rivers, there is not a large area where the coal will probably be found, as the conglomerate comes close to the surface, except on the main dividing ridges between Buffalo, Bylew, First, and Second Creeks. Along the ridge which the Houchin's Ferry road follows, there is from 40 to 75 feet thickness of rock above the conglomerate, until within two miles of Green river, so that, here, the coal has probably been protected from erosion. Of the region, therefore, between Nolin and Green rivers, only that part situated between Nolin river, Bylew, and Dog Creeks, from Wolf Branch down, stated approximately, is furnished with a trustworthy deposit of coal. Beyond this, where found, it is only in detached masses.

Between Bear Creek and Nolin river the Main Nolin coal occurs very regularly and of good thickness, from Decker Branch of Bear Creek south to Green river. Until south of Dismal Creek, the rocks preserve nearly the order and thickness shown in the general section. Here the two coals, below the Bee Spring sandstone, are best developed. From Bee Spring Branch of Dismal Creek south, the Bee Spring sandstone begins to grow thin, and gradually disappears; the coal close below it is seen no more, and the main coal rises rapidly to the south with the thickening conglomerate. From here, south to Green river, this coal is seen at many places, resting close to the heavy conglomerate. The character of the overlying rocks has changed, and no further trace of the second coal is seen. At the Stevens coal bank, near the mouth of Bear Creek, on the west side, as shown by the section already given, there is a thin coal 85 feet above the main coal; but this is the first instance where it is clearly shown.

From Decker Branch to Dismal Creek, the main coal is seen exposed in almost every branch of both Nolin river and Bear Creek. South of Dismal Creek, it is seen close to Nolin river, at Watt Merideth's, above the mouth of Pigeon Creek; but it has not yet been seen in the region drained by Pigeon, Pine, or Indian Creeks. If sought for, at its proper place, above the conglomerate, there is no reason why it should not be found on Pigeon and Pine Creeks, as the conglomerate is, at many places, overlaid by a sufficient thickness of rock to protect the coal. Over a larger portion of the area drained by Indian Creek, as well as the other branches of Green river entering near Brownsville, the conglomerate has been so nearly denuded that it is very doubtful if the coal will be found. If found, it will be only on the highest ridges. In the drainage of Bear Creek, as might be expected from the dip of the rocks, the conglomerate is covered much deeper, and the coal occurs more regularly and over a wider area. It is seen on Sycamore Creek, between Sycamore and Beaver Dam Creeks, on Gulf Creek, at numerous old openings on Bear Creek, near Green river, at the Stevens bank, where the coal is now being mined, and on a short branch entering Green river, just above the mouth of Bear Creek.

At none of these places has it been opened for more than local use, except at the Stevens bank. This is the only locality within the field of the present report where the coal has been mined under ground. It is put into boats on Bear Creek, which is here navigable, and carried down Green river. Throughout the rest of this region the coal is only opened by stripping occasional patches for the blacksmiths of the neighborhood. These openings are usually in the beds of streams, where the coal has been found originally washed bare by the stream. From their position these openings fall in or fill with water almost as soon as they are abandoned, and the coal becomes covered, so that it is impossible to see its full thickness. In many cases, therefore, the thickness of the coal bed has to be taken from the report of those who formerly dug the coal. This is a very untrustworthy way, as the thickness is hardly ever measured accurately by the digger, and in reporting it afterwards, the tendency is almost always to exaggeration. The usual thickness of the coal, reported at these places, is from three to four feet. In some cases it is reported at four feet, with a heavy slate parting; but usually no notice is taken of the partings, and the total thickness is reported, as remembered by the digger.

The average thickness of the Main Nolin coal throughout the region just described, where it has been seen by the writer, is three feet. At many places, where it was reported much thicker, it was found, on examination, that a slate parting or very bituminous slate, which often occurs at the base of the coal, had been measured with the coal, thus greatly increasing its thickness.

It is, however, over most of this field, a trustworthy three-foot coal, and, at many places, it shows free from any parting.

The following section at Knob Lick, near Dismal Creek, is fairly typical of this coal over a large region:

Clay shale, bituminous at bottom	3 feet.	
Coal	3 "	1 inch.
Very bituminous slate		4 inches.
Bituminous slate.	1 "	

QUALITY.

Of the quality of the coals of this region nothing is accurately known, except of the lowest or Main Nolin coal. The other coals are thin, and so rarely exposed that it is difficult to get fairly representative samples. Moreover, not being of workable thickness, it was not considered as of sufficient importance to warrant any great expenditure of time in endeavoring to procure samples of them.

Of the Main Nolin coal a number of analyses have been made, both from single specimens and from carefully averaged samples.

The following analyses of this coal, by Dr. Peter and Mr. Talbutt, will serve to show its quality:

	1	2	3	4	5	6	7	8	9	10	11
Specific gravity	. . .	1.305	1.335	1.282	1.345	1.437	1.350	1.367	1.336	1.395	1.346
Moisture	3.40	4.70	4.06	2.30	2.60	4.06	3.60	3.20	3.66	4.14	6.26
Volatile combustible matter	30.66	31.40	33.24	32.10	33.80	32.00	33.00	33.80	35.14	31.52	32.44
Fixed carbon	54.94	52.20	51.70	56.30	53.14	50.84	54.40	52.60	54.26	56.08	53.80
Ash	11.10	11.70	11.06	9.30	10.46	13.10	9.00	10.40	6.94	15.26	7.50
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Coke	65.94	63.90	62.70	65.60	63.60	63.94	63.40	63.00	61.20	65.34	61.30
Sulphur	2.544	1.945	1.67	1.059	2,425	4.938	2.101	2.923	2.706	3.565	1.476

No. 1 is an average sample, taken by myself, of the coal from the Stevens bank, Butler county.

No. 2 is an average sample, taken by myself, of coal from Tar Lick, near Dismal Creek, Edmonson county.

No. 3 is an average sample, by Mr. J. R. Procter, of coal from same locality.

No. 4 is a single specimen from same locality.

No. 5 is an analysis of a single specimen from Knob Lick, Dismal Creek.

No. 6 is an average sample, by myself, from a small outcrop of coal on Mill Branch of Bear Creek. The outcrop from which the sample was taken was so small that it cannot be safely considered as a representative sample.

Nos. 7 and 8 are analyses of single specimens from the same locality.

No. 9 is an analysis of a single specimen from Shoal Branch of Bear Creek.

No. 10 is an analysis of coal from Gravelly Lick, Miller's Fork of Bear Creek. The sample was taken by myself from a very small outcrop, and cannot be considered as an average of the whole bed.

No. 11. Coal from Brushy Branch of Canoloway Creek; average sample by myself.

These analyses, with the exception of Nos. 6 and 10, show a coal of quality which entitles it to rank among the best of Western Kentucky. The superior quality of the lower coals of the western part of the State has been frequently noted, and is well shown by the above analyses of the Nolin coal, the lowest of the series. The coal varies considerably, at different places, in the amount of sulphur present, but is otherwise, usually, a moderately dense coal, which stands exposure remarkably well, and apparently is sufficiently fat to produce a good coke. At some places the coal is so bituminous that the bitumen flows from the base of it, giving rise to "Tar Springs." This is the character of the coal at the Tar Lick, analyses of which have just been given. At some places where the coal shows the most sulphur, the sulphur is present in a layer or parting of pyrites, which is so thick and persistent that it can easily be rejected when mined, and the remainder of the coal left comparatively free from sulphur.

IRON ORE.

The iron ores of this region are abundant and valuable. It is one of the most richly endowed undeveloped localities in the State.

Iron ores are found in association with the rocks of each geological age in this region, but they are by no means uniformly distributed, nor are they of uniform quality. The region is as yet almost wholly undeveloped, and but little pick and shovel prospecting has been done; so that it is in many cases, impossible to tell of the quantity of ore present when outcrops are found. Doubtless the ores which have been seen will be found, on further investigation, to be more extensive than at first supposed, and ore will be found, at many localities, where it has not been discovered, as yet. It is, therefore, not to be considered as evidence against the continuance of an ore, that it has not been seen at certain localities, unless it has been dug for, or the situation is such that, if present, it must have shown in outcrop.

The ores of this region are mostly in stratified beds, conformable to the rocks with which they are associated. The ores are both limonites and siderites. or earthy carbonates. There is, however, an exception to the rule as to the character of deposit just stated. This is found in the lowest ore of this region, associated with the St. Louis limestone. It is found in the surface clays where the limestone has been much eroded. The ore is thinly scattered, at a great many localities, where the St. Louis limestone is the prevailing rock; but within the field, covered by the present report, it is not apparently in any quantity. The deposits are limited and irregular, and seem to have been formed by the segregation of the ferruginous matter, which was disseminated in small quantities, through the limestone, before its erosion. As the limestone was dissolved away, the iron and the silicious matter in the limestone remained unaffected by the agencies which effected the solution of the limestone ; the iron separating to itself formed the deposits just described, and the silicious residue formed the surrounding clays. The ore is a limonite, which, in some cases, seems to be the original mineral, and, in others, is derived from pyrites, as is shown or proved by the pseudomorphs of limonite, after pyrite found and by the presence of pyrites in the center of some of the largest pieces of ore. This ore is the geological equivalent of the Cumberland river limonites of the western part of the State, which are so valuable and so well known ; but it is by no means as abundant. There are numerous places where this ore shows in quantity sufficient to justify working on a small scale, if there were any market for it, or means of shipment ; but it does not show enough, at any one place, to justify a reliance upon it as a basis of ore supply for a furnace. The ore is usually of excellent quality, except when injured by the presence of sulphur ; but these cases are comparatively rare. It is rarely ever mixed with chert or flint, and is not often silicious to an injurious extent. There were, formerly, iron furnaces in Hart county, which are said to have used ore which is the same as this, with charcoal as fuel, but they are not now in operation, and nothing definite has been learned in regard to them.

The other ores of this region, found in both the Chester and the coal-measure rocks, are stratified deposits of earthy siderite or carbonate of iron, and limonite or hydrated peroxide of iron, derived from the carbonate. At most places only the limonite has been seen ; but it will doubtless be found to change to siderite on following it underground, where there is a sufficient covering to protect it from oxidizing agencies.

At a number of places, ores have been found associated with the rocks of the Chester Group, usually resting upon limestone. On Napper and Saltsman's branches of Bear Creek, there are several exposures of a lean-looking ore, from two to two and one half feet thick. The ore consists of a silicious matrix, inclosing many small nodules of comparatively pure limonite. The ore here rests close under the conglomerate, upon a limestone which is probably the upper one of the series. An analysis was made by Dr. Peter and Mr. Talbutt of an average sample, collected by myself, from an exposure of this ore on Stillhouse Branch, with the following results:

Peroxide of iron	40.798
Alumina	1.293
Lime and magnesia	traces.
Phosphoric acid	1.019
Sulphuric acid	.360
Combined water	7.250
Silica and insoluble silicates	50.030
Total	100.750
Metallic iron	28.519
Phosphorus	.445
Sulphur	.207
Silica	46.760

This shows a high per centage of silica, combined with a low per centage of iron—a combination which renders the ore, for the present at least, of little value.

On Caney Branch of Gulf Creek, one of the lowest branches of Bear Creek, on the farm of Jacob Souders, there is found an ore of excellent quality, a limonite, so far as seen, of remarkable purity. It appears to be in a bed or stratum of about two feet thickness, resting under shales, upon or near the top of a limestone, the exact equivalency of which was not determined, as the exposure was small, and the undulations or irregularities of the strata soon carry it below the bed of the creek, both above and below. The heavy conglomerate sandstone, showing cliffs from 50 to 100 feet high, is seen immediately above the ore; but the base of it is covered, so that the exact distance of it from the ore could not be ascertained; but it is probably not over from 10 to 20 feet. This sandstone comes down to the bed of the creek, both above and below the locality where the ore and the limestone are exposed. The distance within which the limestone is exposed above the drainage is from one third to one half mile along the Creek. The limestone is probably not the upper member of the Chester Group, as it is in the region of the heavy conglomerate, where the upper members of the Chester have probably been carried away at the time of the deposition of the conglomerate. In quality this ore is among the best of this region; and if it can be found to extend over any great area, it will prove one of the most valuable. It has been found outcropping in considerable quantities on the farm of M. Honaker, on Green river, above the mouth of Bear Creek. Enough is here seen to indicate with considerable certainty that this is the same ore, and that it is present in considerable quantity. At numerous other places, traces of this ore have been found, but nowhere else so promising. At other localities, where the Chester are the prevailing rocks, small surface outcrops of ore have been found; but as yet they have not been prospected, and it is impossible to tell anything definite as to the amounts. It is probable that, with careful prospecting, many of these will be found more valuable than now supposed.

The first iron ore of the coal measures rests immediately upon, and, in fact, is often mingled with, the conglomerate. The ore varies largely in its character, but is usually distinguishable by the quartz pebbles which are scattered through it in greater or less quantities.

The exact relation which this ore bears to the coal which rests close to the conglomerate is still a matter of some obscurity. At some places the coal has been seen resting immediately on the conglomerate, and at others the pebbly ore occupies exactly the same position; but a satisfactory section, showing the two together in one hill, has not been obtained. At Watt. Merideth's, on Nolin river, above the mouth of Pigeon Creek, the ore was found on the surface, in a position which indicates that its position is below the coal. The coal was found in sinking a well, and no ore was found above it, thus indicating with certainty that the position of the ore is here below the coal, although it cannot be far. Further southwest, on Beaver Dam Creek, the coal is seen resting almost immediately on the conglomerate, with no room for the ore below, and no sign of its presence above. It is by reason of the uncertainty that attaches to the relative position of ore and coal, that the lines indicating their places have not been carried south of Pigeon Creek, in the cross-section No. 2, from Grayson Springs Station to Green river. Further north, at many places in the region north of the heavy conglomerate, an ore is found resting upon the Main Nolin coal, which, in its turn, rests close to the conglomerate, with no ore between. This ore differs in character from the other; is usually leaner, more porous, thinner, and does not carry any pebbles. Its usual thickness is from six to eight inches, although occasionally thicker. The thickness of the conglomeratic ore is not well shown at many places, but it seems to vary from one to two feet, and occasionally thicker. It is very variable in both quality and thickness, changing suddenly from a nearly pure limonite ore to a ferruginous conglomeratic sandstone, in a very short distance, and making correspondingly great changes in thickness at the same time. The ore, so far as seen, is all limonite. It has not been opened, at any place, far enough to reach the unaltered carbonate.

The following analyses, by Dr. Peter and Mr. Talbutt, will serve to show the quality of this ore:

	1	2	3
Peroxide of iron	55.028	47.724	32.820
Alumina	1.006	2.501	2.356
Brown oxide of manganese	.040	.....	.....
Carbonate of lime	trace.	trace.	trace.
Magnesia	.108	trace.	trace.
Phosphoric acid	.312	.065	.984
Sulphuric acid	.133	.315	.285
Combined water	8.300	8.250	8.330
Silica and insoluble silicates	35.180	41.145	55.180
Total	100.107	100.000	99.955
Metallic iron	35.519	33.407	22.974
Phosphorus	.135	.028	.430
Sulphur	.053	.125	.114
Silica	33.70	39.560	48.960

No. 1 is an analysis of a single specimen of conglomeratic limonite ore from Mrs. Bythe Merideth's, near the mouth of Dismal Creek. Specimen selected by Prof. N. S. Shaler.

No. 2 is an analysis of an average sample, taken by myself, from an exposure of the conglomeratic ore above Thomas Merideth's, on one of the branches of Dismal Creek, from the south.

No. 3 is an analysis of an average sample, by myself, from the ore resting upon the Main Nolin coal, on Mill Branch of Bear Creek.

Nos. 1 and 2 show the conglomeratic ore at its best. It proves to be better in reality than its looks would indicate; and if it can be relied upon to continue of this quality, it will prove a very valuable ore. Of this there is some doubt; but it will doubtless be found of this quality at many other places.

Analysis No. 3 indicates an ore much poorer than it appears to be. The ore here is porous and sandy, but does not, to the eye, appear nearly so silicious as the analysis proves it to be. It is so poor in iron, and so silicious, that for the present, at least, it is of little value. From its position immediately above the coal, this ore could be mined very cheaply if it were sufficiently rich in iron to justify its use.

Near Old Nolin Furnace, on Davis Branch of Nolin river, there is an ore which occurs between the lower conglomerate and the Bee Spring sandstone. Its place is about 30 feet above the conglomerate. This ore is said to have been used in considerable quantities when the furnace was in operation. It is from three to four feet thick where seen, and very lean. There is evidence of considerable digging at the place where the ore was seen. The analysis shows that the ore is very silicious and poor in iron. The sample analyzed was, however, selected from only a very small surface of the ore, which was uncovered for the purpose, and it may have been worse than the average of the bed. The sample was taken to represent the outcrops exposed, as accurately as possible. The ore is quite fossiliferous, being composed at places almost entirely of the shells of fossils, and it varies in quality. It must be, therefore, that the sample was taken from a place where the ore is more silicious than usual, although it was not known at time of sampling. An ore yielding only 19 per cent. of iron could not be profitably worked in the furnace.

The following is the analysis by Dr. Peter and Mr. Talbutt:

Peroxide of iron	27.340
Alumina	5.930
Carbonate of lime	1.090
Carbonate of magnesia	.447
Phosphoric acid	1.068
Water expelled at red heat	12.380
Silica and insoluble silicates	51.230
Undetermined and loss	.515
Total	100.000
Metallic iron	19.138
Phosphorus	.497
Silica	47.360

This ore has not been recognized at any other locality, but occasional thin bands of clay carbonate are found in the shales, between the conglomerate and the Bee Spring sandstone. These are usually of very good quality; but they have never been mined, and little is known as to their horizontal extent. Many surface outcrops of ore have been found through this region, which could not be traced to their position with the means at command. Many of these promise well, and show ore of very good quality; but little can be learned of their quantity without digging. This is especially the case east of Nolin river. Several promising surface outcrops of very good ore have been seen here. One of them, near Wm. Saunders', on Brier Creek, shows limonite of very good quality, which seems to belong on top of the lower member of the conglomerate; but nothing definite as to position or thickness. At another place, near the Mammoth Cave road, about one mile from Mt. Vernon Mill, surface limonite was found in considerable quantity upon the Bee Spring sandstone, which is here conglomeratic, as is also the ore. There are obscure indications that the sandstone consists of two members here, and that the ore belongs between them. It is certain that the position of the ore is not far above the sandstone.

Above the Bee Spring sandstone is found, apparently, the most regular and promising ore of this region. This is best seen at the old banks, on the Nolin Furnace property, where much ore was formerly obtained for use at the furnace. These banks are on the ridge at the head of Decker Branch of Bear Creek. The ore is 35 feet above the Bee Spring sandstone, which is here characteristically developed, about 50 feet thick, with the two coals below it.

There are two banks near the Brownsville and Leitchfield road, about two miles apart. At the most southerly of these, the ore is reported to be six feet thick, and it was seen between three and four feet in thickness, of which the upper portion was ore of very good quality; the lower was sandy and ochreous. This bank is between three and four miles north of Bee Spring, between Decker and Davis Branches. A little over two miles north of this is a bank, exactly six miles from Bee Spring, which shows ore of very good quality, two feet in thickness. The ore from this bank is reported to have been the best, in quality, of any ever used at Nolin Furnace. It is, in fact, of excellent quality, as shown by analysis No. 3 of the following table. The same ore is found near McGrew's, on one of the streams of Hart Branch of Bear Creek, showing about two feet thick, although no digging has ever been done, here, to expose its full thickness. Further north, the ore has not been distinctly recognized. It probably thins in that direction, and soon disappears altogether, simultaneously with the change in the character of the Bee Spring sandstone.

South of Bee Spring, on the heads of Sycamore and Beaver Dam Creeks, an ore is found 60 feet above the heavy conglomerate, and from 15 to 20 feet above a sandstone which seems to be the thin edge of the Bee Spring sandstone. This ore is somewhat different in character from that last described, but it is not unlikely the same ore. It has only been seen as a limonite, which is oölitic and rather coarse-grained, appearing more silicious than it really proves to be on analysis. It is a "block" ore, occurring in layers, which cleave into rectangular blocks. It is between three and four feet thick where seen, but in the opinion of the writer will probably average near the lower figure.*

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*This ore has been distinctly seen in but two places, and in these it exceeds four feet in thickness, by my measurements. N. S. S.

The quality of this ore, and that of the old Nolin Furnace banks, is shown by the following analyses by Dr. Peter and Mr. Talbutt:

	1	2	3	4
Peroxide of iron	52.926	49.906	57.830	48.913
Carbonate of iron	. . . . .	. . . . .	. . . . .	5.735
Alumina	4.792	3.330	6.719	7.125
Brown oxide of manganese	.210	. . . . .	. . . . .	. . . .
Carbonate of lime	.180	trace.	.290	9.410
Magnesia	.425	trace.	.122	.144
Phosphoric acid	.355	.694	.921	.489
Sulphuric acid	.143	.395	. . . . .	.199
Combined water	10.400	9.320	12.180	8.905
Silica and insoluble silicates	30.580	39.780	21.040	19.080
Total	100.011	100.425	99.102	100.000
Metallic iron	37.048	34.407	40.481	36.526
Phosphorus	.154	.303	.412	.209
Sulphur	.057	.158	. . . . .	.080
Silica	29.160	33.461	14.360	17.820

No. 1 is an analysis of an average sample, taken by Prof. N. S. Shaler, from a bank called the "Federick bank," at the head of one of the branches of Beaver Dam Creek, near where the Little Mountain road leaves the Leitchfield and Brownsville road, Edmonson county.

No. 2 is an average sample, taken by myself, from an exposure of the same ore, near the head of one of the branches of Sycamore Creek, Edmonson county.

No. 3 is an average sample, by myself, of ore from one of the old Nolin Furnace banks, on the Leitchfield road, six miles from Bee Spring, and nine miles from Grayson Springs, Grayson county.

No. 4 is an average sample, selected by myself, from another of the old banks of the Nolin Furnace, about three and one half miles north of Bee Spring, west of the road, at the head of one of the forks of Decker Branch.

These analyses show a good workable per centage of iron in all of the samples, and not enough of any injurious ingredients to affect their value to any extent. The per centage of silica is rather high in No. 2, and phosphorus in No. 3, but it is by no means enough to prevent their use.

These ores, whether they be the same geologically or not, are the most valuable in all this region. They alone promise to furnish a sufficiently reliable supply of ore upon which to base a manufacturing industry. There are many square miles of area over which these ores will, probably, be found. As yet, little prospecting has been done, and the opportunities for observing the variations of the ore, as well as for ascertaining the fact of its occurrence at any locality, are very poor. It has been observed, however, at enough localities to obtain its geological position accurately, and at localities far enough separated, to justify the conclusion that it is of more than local occurrence. It is probable that it will be found, at many places, between the outcrops at present known, where it is now not supposed to exist. Its best development is, of course, in the main dividing ridge between Nolin river and Bear Creek; but it will be found out on the spurs of the ridge between the branches, wherever there is a sufficient thickness of rocks above the Bee Spring sandstone to hold and protect the ore. There are, however, many places on the main ridge, even where the Bee Spring sandstone comes so near the surface, that the ore will not be found. It may be stated as a rule, for the benefit of prospectors, that it will be of no use to look for this ore unless there is at least a thickness of from 40 to 50 feet of rock above the Bee Spring sandstone, where it is characteristically developed, or of 65 to 75 feet thickness above the heavy conglomerate, where that is the prevailing rock. When this rule is borne in mind, it will be very easy to tell, at any locality, whether there is a possibility of finding the ore or not.

South of Beaver Dam Creek no prospecting has been done, although there is a considerable area in which the thickness of rock above the conglomerate is sufficient to protect the ore. In the Brownsville road, about three miles from Green river, there is some ore exposed, which is probably the outcrop of the same, although it has not been definitely determined.

South of the Morgantown road, in the drainage of the small streams flowing directly into Green river, the conglomerate is so near the surface that in but few isolated patches can we expect to find the ore.

The region where this ore will be found is, therefore, approximately, bounded on the south by the ridge at the head of the short streams flowing directly into Green river. Its limit to the north has been already given. East of Nolin river, this ore has not been recognized. Near the river, there are numerous hills which are high enough to hold the ore; but these are not found further than three or four miles from the river.

West of Bear Creek, little work has been done, and little or nothing is known of the existence of the ore in this direction. The field of the ore, already known, is sufficiently large to furnish a reliable supply of ore upon which to base an iron industry.

On the Nolin Furnace property, at the head of one of the forks of Davis Branch, 25 feet above the main ore, is another ore bank, where a sandy ore nearly two feet thick is said to have been obtained for use at the furnace. This is the highest ore of the general section, and has been recognized at no other place. The ore was covered so that not enough of it was seen to judge of its quality.

OTHER ORES.

At several other localities in this region, ores have been observed which have not been given a place in the general section, for the reason that they seem to be local. Some of these show ore of as excellent quality as any in this region. The fact, however, that they have not been found elsewhere, in a region where so little prospecting has been done, is not of itself conclusive that they are local. They may, hereafter, be found to be reliable and extensive deposits.

One of the best known of these occurs on a hill between two branches of Sycamore Creek, about two thirds of a mile west of the Brownsville road. It is called the Procter ore bank. The ore is a limonite, freer from silicious matter than almost any other in this region, but exceedingly fossiliferous. It occurs on the top, and extending some distance down the slope, of an unusually high knob. Some prospecting has been done, but no bed or solid mass of ore has been found; it only occurs in lumps of small size. The character of the ore, and its occurrence in this manner, indicate that it is the remnant of a destroyed stratum or bed of ore, the original position of which was some distance above where it is now found. It was probably a bed of very pure fossiliferous carbonate of iron originally; but the long-continued exposure to oxidizing agencies has converted it into limonite, while the erosive agencies were destroying its identity as a bed. The position of this ore, where found, is considerably above the main bed of ore on Sycamore Creek. The following analysis by Dr. Peter and Mr. Talbutt, from a single specimen, shows the excellent quality of this ore:

Peroxide of iron	76.284
Alumina	2.361
Brown oxide of manganese	.030
Carbonate of lime	.180
Magnesia	.068
Phosphoric acid	1.055
Sulphur	.151
Combined water	12.000
Silica and insoluble silicates	7.951
Total	100.080
Metallic iron	53.399
Phosphorus	.460
Sulphur	.059
Silica	7.660

Another of these ores is shown in the section already given, at Stevens' coal bank. It is the ore above the upper coal, and is about six inches thick. Its quality is shown by the following analysis by Dr. Peter and Mr. Talbutt. The sample analyzed was taken from a very small outcrop of the ore, so that it may not be fairly representative, but it is believed to be as good as the average:

Peroxide of iron	44.974
Alumina	2.391
Carbonate of lime	.643
Magnesia	.234
Phosphoric acid	.535
Sulphuric acid	.158
Combined water	7.700
Silica and insoluble silicates	44.180
Total	100.815
Metallic iron	31.482
Phosphorus	.233
Sulphur	.063
Silica	42.20

On Taylor's Fork of Bear Creek, on a branch entering at M. Ray's, about two miles from Leitchfield, an ore is found, under a heavy sandstone, at a chalybeate spring. The ore is about seven inches thick where seen, and of very good quality, partly limonite and partly the unaltered carbonate. On the opposite side of the branch the same ore is seen, apparently considerably leaner, while the sandstone does not show above. The following analysis by Dr. Peter and Mr. Talbutt, from a sample of this apparently lean ore, shows that it is rich enough in iron to be valuable. The ore on the opposite side of the branch, at the spring, is much richer than this:

Peroxide of iron	44.528
Alumina	1.368
Carbonate of lime	5.590
Carbonate of magnesia	.609
Phosphoric acid	1.074
Sulphuric acid	.151
Combined water	8.940
Silica and insoluble silicates	37.380
Total	99.620
Metallic iron	31.169
Phosphorus	.468
Sulphur	.060

At many other places ores have been found, in greater or less quantities, in surface outcrops; but usually when the quantity was sufficiently great to render them worth attention, the quality has proved to be poor; and *vice versa*, when the quality was good, the quantity was so small that, without further prospecting to prove the extent greater, they have not been deemed worthy of mention. Beyond the field of the map, west of Bear Creek, near Green river, in Butler county, a number of these ores have been examined. They are mostly bands of clay carbonate, in the heavy shales which overlie or replace the conglomerate. The ores do not seem to be continuous, but are independent beds at various levels. Some of these are of very fair quality, but thin, ranging from three to six inches in thickness. The most promising outcrop was found at John Hudson's, on the Young's Ferry road, about two miles from Green river, where is a bed of carbonate of iron fourteen inches thick, of which the following is an analysis by Dr. Peter and Mr. Talbutt, from an average sample, taken by myself:

Carbonate of iron	29.914
Peroxide of iron	17.945
Alumina	3.583
Carbonate of lime	12.036
Carbonate of magnesia	3.677
Phosphoric acid	.467
Sulphuric acid	.380
Silica and insoluble silicates	28.040
Water and loss	3.957
Total	100.000
Metallic iron	27.041
Phosphorus	.204
Sulphur	.152
Silica	25.260

This ore, by roasting, can be brought to yield over 30 per cent. of iron, while the considerable per centage of lime present will render it an easy working ore.

In the old Brownsville and Leitchfield road, on the first high hill west of Bear Creek, about four miles from Leitchfield, on land belonging to John Higdon, is a bed of ore, partly limonite and partly carbonate, resting on the shales near the top of the hill. The ore is about eight inches thick, and of excellent quality, as the following analysis, by Dr. Peter and Mr. Talbutt, of an average sample, taken by myself, shows:

Carbonate of iron	16.598
Peroxide of iron	42.761
Alumina	4.994
Carbonate of lime	2.840
Carbonate of magnesia	2.904
Phosphoric acid	1.017
Sulphuric acid	trace.
Silica and insoluble silicates	20.830
Water and loss	8.056
Total	100.000
Metallic iron	37.945
Phosphorus	.444

Near the mouth of Hunting Fork of Rock Creek, a small outcrop of excellent ore was found, not far from the top of the Chester limestone; but it was seen in only one locality, and it is not certain if it be a reliable deposit. Its quality is equal to that of any in this region.

On Grindstone branch of Rock Creek, a fossiliferous limonite was found, but proved to be so lean that it is probably of little value.

This closes the list of ores in this region which have been deemed worthy of description. Most of them have been seen at but few outcrops, and may have been judged to be local from insufficient evidence. There is, however, in a large portion of this region a trustworthy supply of ore, sufficient to sustain a number of furnaces. Most of the region is covered with timber suitable for charcoal, which can be obtained at a small cost, and sometimes for the cutting. Of stone-coal there is an abundant supply of good quality, which can be mined cheaply and easily. It will, however, probably be best to coke it, if it is desired to use it for the manufacture of iron. Limestone for flux is also abundant in nearly every stream. The region furnishes, therefore, all the requisites for the manufacture of iron in quantities sufficient, and at prices low enough, to produce cheap iron. The most serious disadvantage which it has, and the one which has prevented its development hitherto, is lack of transportation facilities. The distance from the Louisville, Paducah and Southwestern Railroad to the nearest valuable ores is from ten to twelve miles, while on the south, it is about six miles from Green river to the ore banks best known at present. This distance is from the river at Brownsville, above the head of slack-water navigation, although, for perhaps half the year, boats of light draught can ascend to Brownsville. The building of a dam across Green river, below the mouth of Bear Creek, would give slack-water navigation to Brownsville, and render Bear Creek navigable to small boats, so that access could be had to the ores.

The necessity of wagoning iron to the railroad, involves so great an expense per ton that it is probable stone-coal iron could not now be made, in this region, at a profit; but a high grade of charcoal iron, either cold or hot blast, as it is a more valuable product, could stand a greater expense per ton for transportation and yet yield a profit.

The Nolin Furnace, which has been frequently referred to, was compelled to suspend operations largely from this cause. It was built in 1844 or 1845, near the mouth of Davis Branch of Nolin river, in Edmonson county. It ran three or four years, and then suspended operations. It has never since been started. The only means of getting out the iron was to run it down Nolin river in keel-boats, at time of high water—a method so uncertain and irregular in its operation that it, in addition to the limited capital of the owners, proved fatal to the enterprise. The furnace used charcoal for fuel, and made only cold blast iron. The iron made was of excellent quality. In the last days of its operation the furnace was run almost exclusively with the ores from the banks above the Bee Spring sandstone, on the ridge between Nolin river and Bear Creek.

A piece of pig iron made at this furnace was obtained, and analyzed by Dr. Peter and Mr. Talbutt. The following is the analysis:

Iron	94.287
Graphitic carbon	3.100
Combined carbon	.700
Silicon	.493
Phosphorus	1.029
Sulphur	.012
Total	99.611

The iron is a fine-grained, cold blast iron of great strength. The noticable feature of the above analysis is the small per centage of silicon and the high per centage of phosphorus. The strength of the iron is due to the low per centage of silicon; for with the ordinary amount of silicon present, added to the phosphorus, the iron would be very brittle. The phosphorus is higher than is usually possible without making a cold-short iron. The amount of phosphorus in this iron shows that nearly all of that ingredient in the ore is reduced, and passes into the pig. This furnishes an additional reason for smelting these ores with charcoal, as with that fuel, silicon and other impurities are not so liable to be reduced, and alloy with the iron, to its great injury.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, Director.

TOPOGRAPHICAL REPORT

OF THE

NOLIN RIVER DISTRICT,

BY WILLIAM BYRD PAGE.

INTRODUCTORY LETTER.

Professor N. S. Shaler, *Director Kentucky Geological Survey:*

Sir: I herewith submit the following report upon the topography of the Nolin River district:

In accordance with your instructions of June 3d, 1874, designating for field work the country from Green river north towards the Ohio, and the object the delineation of the eastern outcrop of the western coal field, field work was commenced on the 10th of June, 1874, and continued without intermission until the 24th of December of the same year. In connection with this work, a meridian line was established at Brownsville; stones were placed in the line, and the declination of the magnetic needle determined. A map showing this line, and the position of the stones, was placed on record at the court-house at Brownsville.

A map of an Indian fort near Honaker's Ferry, on Green river, was also made.

The map of the Nolin River district was drawn upon a scale of six inches to the mile, to be kept as a record, and reduced for publication to one inch to the mile.

In the field work, material aid was rendered by Messrs. C. W. Beckham and J. B. Marcou, to whom an acknowledgment is due for their energy and interest during the prosecution of the work.

Upon leaving the field, the office work was commenced and continued until the map was prepared for publication.

Very respectfully,

WM. BYRD PAGE.

TOPOGRAPHICAL REPORT OF THE NOLIN RIVER DISTRICT.

The topographical survey of this section extends northward from Green river to the Louisville, Paducah and Southwestern Railroad, and from Bear Creek, on the west, eastward to the Mammoth Cave, including the lower portion of Green river. The extent of area mapped is about three hundred square miles. This area includes portions of Edmonson, Grayson, and Hart counties, and the county towns of Brownsville and Leitchfield. The Mammoth Cave and Grayson Springs and its railroad station are also shown.

THE METHOD OF THE SURVEY.

The following is an outline of the method pursued in mapping this section: The road from Brownsville to Grayson Springs Station was selected as a base line. This road was surveyed with transit and chain, and over the transit line a profile of the road was made with a water level. This line served as a base for the compass work, and, as far as possible, the surveys were closed to it. The profile enabled the barometric work to be checked. Barometric observations were made upon all the compass lines, and from these observations contour lines were shown upon the map.

DRAINAGE.

The drainage of this section is entirely to Green river, and in a southward direction, making this area a portion of the northern water-shed of the river.

The principal channels of drainage are Nolin river and Bear Creek.

The surface rock, the character of which determines the shape and relative positions of the contours, is, over much of the surface, sandstone. This is shown in the table-land structure of the area in the western portion mapped. The limestone structure, which is flatter and of more irregular form, is confined chiefly to the eastern portion of the district, and to the valleys or bottom lands of the rivers and creeks. Where the shales come to the surface there are characteristic knobs. The thickness of the sandstone gives an additional variety to the features of the country. The height of the table-land will average about 350 feet,* and will vary from 250 feet to 500 feet, the general level rising toward the east. The more important portions of the country will be described in detail.

The head branches of Bear Creek drain the country southward from the railroad, from east of Grayson Springs Station to west of Leitchfield. About four miles from the road, these streams meet at a level about 200 feet below the road.

Lizard Lick Branch, heading at the Springs Station, empties into Bear Creek at Grayson Springs. Here the level of the creek is 175 feet below the railroad.

These branches have no precipitous cliffs or falls, but regular and gradual slopes, mostly covered, and, as they approach Bear Creek, widen into flat bottom lands. From Grayson Springs the general course of Bear Creek is south southwest, and its length, to the mouth, is 41 miles. It is tortuous in its entire length. In air-line, the distance is 22 miles from the Springs to the mouth of Bear Creek. The total fall of the creek in this length is 130 feet. The table-land ridges between Bear Creek and Nolin river and its branches may be considered as spurs of the ridge upon which the Louisville and Paducah road, near the Springs Station, is built. These ridges extend to Green river. At the railroad the ridge is about 325 feet in height above Green river. Where first shown on the map, it is crossed by the road from Grayson Springs to Morrison's Ford, on Rock Creek. Its extreme height at this road is 350 feet. One mile south it is crossed by another road from Grayson Springs to Rock Creek. Here the streams of Bear and Rock Creeks head close to each other, and cut down the ridge to a height of 300 feet. One mile further, at the junction of the Grayson Springs, Mammoth Cave, and Brownsville roads, the ridge attains a height of 340 feet, and is divided by Canoloway Creek. This creek is about six miles in length; its slopes are gradual and mostly well covered. The branches from the southwest show exposed cliffs. The total fall of this creek, from its head to Nolin river, where it empties, is 310 feet.

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* Vertical measurements are given in feet above low water of Green river, which datum is 436 feet above the level of the sea.

The spur of the ridge, upon which is the Mammoth Cave road, preserves its height evenly for some miles. The creeks, as they drain either side of the table-land ridge, show, by their precipitous drop of about 60 feet, the character and thickness of the surface rocks. Three miles from Nolin river the ridge is cut down, and the branches on either side head to the saddle. The ridge to the river gains its original height only at intervals.

The spur of the ridge, upon which is the Bee Spring and Brownsville road, extends in a southerly direction towards Green river. Its height varies considerably, although the same character of table-land exists. Five miles from Grayson Springs, where the Leitchfield road is, the ridge attains its greatest height of 400 feet. Just to the east of this point is a knob about 40 feet higher than the road. From this point to Bee Spring, a distance along the ridge of 10 miles, the height varies from 390 to 270 feet. From Bee Spring the ridge rises to 370 feet, at the Little Mountain road, 3 miles south of the spring.

From here to the southward, although the surface is without apparent change, the creeks indicate, in many points, remarkable alterations. Pigeon, Pine, and Indian Creeks, draining into Nolin and Green rivers on the east, and Beaver Dam and Gulf Creeks of Bear Creek on the west, after a short, gradual, covered slope, break over the heavy conglomerate sandstone in perpendicular cliffs. These cliffs vary in height from 60 and 70 to over 100 feet. From the bottoms of the creeks they rise almost vertically on either side. Here is seen the

Rock-House structure, where the lower portion of the sandstone has receded and the upper part makes a roof, giving good shelter and room. The rock-houses vary much in size; the dimensions of one measured were 100 by 40 by 60 feet.

East of Rock Creek appears the first general erosion of the sandstone, the sandstone table-land structure being replaced by the flat but irregular limestone type of topography. The ridge between Rock Creek and Nolin river has been protected, and remains capped with sandstone. This ridge attains a height, in places, of nearly 500 feet. The lowest gap in the ridge is between Hunting Fork of Rock Creek and Laurel Run of Nolin river. Its height is 300 feet. The ridge towards Rock Creek will average in height from 350 to 400 feet. This ridge does not extend further north than Sinking Creek. This creek is so named because it has no outlet above ground. The bed of the stream has no continuous slope towards the mouth, but a rise of 20 or 30 feet in one or more places. To the northward of Sinking Creek the area remains flat. The country between Nolin and Green rivers presents several curious features of topography. The structure is of the sandstone type and partly of the thickened conglomerate sandstone variety.

The streams head to a common point, which is about 480 feet high. The descent to the bottoms of the creek is very precipitous, and from the bottoms the cliffs extend along almost the entire length of the creeks as vertical walls.

To the valley of Bylew Creek there are said to be only three approaches. In the valley the arable land is of some extent. The heights of the vertical cliffs were measured in several places, and are given below. Bylew and Piney Creeks cut through the thickest of the sandstone, and the cliffs in these creeks are almost unbroken in their wall-like appearance. In some places the cliffs will measure 180 feet. Buzzard's Roost, on White Oak Fork of Dog Creek, is a picturesque overhanging cliff of 160 feet in height. This peculiar structure is confined to the following creeks: First Creek and Gulf on the south, Pigeon, the mouth of Dismal, Piney, and the western branches of Dog Creek on the north, the western branches of Dog and Buffalo Creeks on the east, and on the west extending to Gulf and Beaver Dam Creeks. The heights of the cliffs were measured in a few places on Green and Nolin rivers. At the mouth of Indian Creek, on the north side, the cliff is 198 feet in height; at the mouth of Nolin river, on the western bank, 175 feet; at the mouth of Second, 209 feet, and Dismal Rock, opposite the mouth of Dismal Creek, is 164 feet in height.

LINES OF ACCESS.

The nearest railroad is the Louisville, Paducah and Southwestern. This road skirts the northern boundary of the country. Grayson Springs Station is distant from Louisville 65½ miles. A branch line from this road 15 miles in length would place, at the road, the coal and iron together with the timber and other produce of this section. The probable routes would present no peculiar difficulties. The ridge extending from the road to Green river has been described in detail as a practical route for the road, and the map has been worked closely along the probable line. This will enable the route to be chosen without much expense of preliminary surveying. Should it be advisable that the road pass Grayson Springs, Lizard Lick Branch presents suitable slopes, and the approach to the ridge could be made by the School-house Branch of Bear Creek. This route would not lengthen the road appreciably.

To the southward of this section of the country is the Louisville and Nashville road, 8 miles south of Green river, and 7 and seven eighths miles south of the Mammoth Cave, by railroad survey. A branch road into this section of the country would give an abundant supply of coal to this road, at a most convenient point, midway between the termini of the road.

RIVERS.

This section has great advantages in the facilities which its rivers will afford. Green river, as shown in this area, is about 200 feet wide, a deep stream, rarely freezing, and with slight fall per mile. Slack-water exists already within the limits of the map, and the distance by the river to the Ohio is 283 miles. The highest lock on the river is near the mouth of Barren river, 19 miles below the mouth of Bear Creek.

Slack-water facilities could be given to this section at small expense. This would also affect Nolin river and Bear Creek. Mt. Vernon Mills, on Nolin river, would be brought within the limits of slack-water, and within the reach of a market for the valuable timber which it offers.*

WATER POWER.

The country has superior advantages in this respect. The volume of flow in the rivers will be mentioned later. Springs are numerous, and may be divided into two classes—limestone springs and those flowing from the sandstone. The former are large in volume, with comparatively small fall; the latter are smaller in volume but more numerous, and are in such relation to the vertical cliffs as to have effective falls of considerable height. Both classes of springs represent power, and are susceptible of use. Upon the map is shown the quantity of running water of many of these springs; the quantity for twenty-four hours is given, and from the contours the effective fall in any distance can be determined.

The volume of some of the springs may be mentioned here. At Grayson Springs one spring measured 30,000 gallons. On Slab Run and Barlow's Run are two springs, measuring about 40,000 gallons each. On Beaver Dam Creek is a mill dependent on a spring for its supply; the effective fall is about 30 feet. A spring at the mouth of Nolin river has an effective fall of 90 feet, and was flowing, when measured, about 70,000 gallons. Used, as it is at present, for a mill, about half the power is lost. Dog Creek should be mentioned as furnishing a considerable supply of running water. Its banks are suitable for high dams. The mills on the creek represent good power. A spring near Nolin at Broad Ford, higher on the river than shown on the map, measured over 4,000,000 gallons. The volume of flow of Nolin was measured in May, 1875; it was then said to be below its average for the year, exclusive of freshets. The volume was over 8,000 cubic feet per minute, which is equivalent to 15.1 horses' power per foot of fall, or for the dam, 7 feet in height, at Mt. Vernon Mills, there was represented 108 horse-power. The river has measured, at other times, when considered just beyond its usual flow, 48 and 68 horse-power per foot of fall.

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* See water power at dam, as given below.

Green river, when gauged in May, 1875, was about 10 feet above its ordinary summer level. The volume was measured at the Brownsville ford, and amounted to 430,000 cubic feet per minute. This volume does not give an idea of the average flow, as the river was much beyond its ordinary stage.

For irrigation, the water of the streams and branches can be made of service. In many cases it can be led around the slopes by natural flow; or where there is enough water it can be pumped, by water power, to a desired height and led over the land. The water of heavy rains, causing the subsequent heavy wash, which, in the bottom lands of the creeks, are so destructive, could, with small expense, be so held back and spread upon the land, that it would leave upon it the rich soil in suspension, the benefits of which would be considerable. The difference between head-water and back-water rises is well understood on the river bottoms; the former washing the soil, and taking off fences, &c., the latter, on the contrary, depositing on the lands submerged the sediment in suspension, the value of which is shown in the succeeding crops. The construction of dams for the purposes of slack-water will tend to increase the chances for back-water rises.

ROADS.

The roads of this section have never been improved to any extent. The ridge roads are generally good, the sandstone making excellent road-beds. The roads in the bottom lands, upon the limestone or shales, are easily cut, and often heavy. The difficult parts of the roads are the slopes to and from the bottom lands to the table-land ridges. In some cases these slopes are well selected, but they do not receive work in sufficient amount. Portions of the roads are frequently changed, and generally to unsuitable ground. This is often done for the benefit of a single individual to the detriment of the public, the only advantage being the saving a single line of fencing. If this is not remedied, the country will be much injured. No portion of a road should be changed without an examination being made by competent authority from a plan and profile of the original and of the proposed road. Many of the worst features noticed were due to these changes to unsuitable ground.

ESTABLISHMENT OF A TEST-MERIDIAN AT BROWNSVILLE.

In connection with the survey of this section, the direction of a meridian was determined and marked by stone monuments. The magnetic declination was also ascertained. The monuments were placed (165) one hundred and sixty-five feet apart.*

These monuments were intended as a check upon the errors of the instruments used for land surveys; the distance between them to test the accuracy of the chain. The discrepancies in the length of chains are often as much a source of error as the inaccuracies of the compass. The monuments are accessible to the surveyors of the several adjacent counties. With little trouble the compasses and chains in use by the surveyor could be tested and the discrepancies recorded. This would not only check compass and chain in use for each survey, but in a few years a table of the variation of the declination, so necessary in the re-survey of old lines, could be made. Although these points may not be considered as very important at the present time, they will become indispensable as the lands of the State increase in value, and subdivisions become necessary.

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*The length, 165 feet, is equivalent to 5 half-chains. The half-chain (33 feet) is used in this section of country.

The monuments were placed in the Brownsville court-yard, and covered for protection. A plan showing their position was placed upon record at the Brownsville court. The points on the monuments are marked by copper bolt and cross-lines.

This section of country, from its proximity to two important lines of railway, and with its natural advantages of water transportation, demands, and will in a short time find, a market for its produce and mineral wealth.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

REPORT

UPON THE

AIRDRIE FURNACE AND PROPERTY,

MUHLENBURG COUNTY, KENTUCKY,

BY P. N. MOORE.

INTRODUCTORY LETTER.

Professor N. S. SHALER, *Director Kentucky Geological Survey:*

SIR: In accordance with your instructions, I made, during the past summer, an examination of the Airdrie Furnace and property, with a view to ascertain something of the resources of the estate, the causes of the former non-success of the furnace, and to suggest, if possible, the means whereby it can be brought into successful operation. The time at my command did not suffice for a careful geological examination of the whole property, and my attention was therefore given only to that portion in the immediate neighborhood of the furnace. It is to this that the furnace must look for its supply of fuel for a long time to come, and, as on examination it proved sufficiently rich in coal to place the matter of a sufficient supply beyond reasonable doubt, little attention was given to any other part of the property.

P. N. MOORE, *Assistant.*

LEXINGTON, KY., December, 1874.

REPORT UPON THE AIRDRIE FURNACE AND PROPERTY, MUHLENBURG COUNTY, KY.

SITUATION.

Airdrie Furnace is situated near the village of Paradise, Muhlenburg county, Kentucky, on the bank of Green river, one hundred and thirty miles above its mouth, eighty-five miles below the head of slack-water navigation at Bowling Green. It is also four miles above Rockport, where the Louisville, Paducah and Southwestern Railroad crosses Green river, a stream which furnishes slack-water navigation for two hundred and fifteen miles, at nearly all times of the year, to boats drawing four feet of water; and during the greater portion of the time is navigable for boats drawing six feet.

There are but two locks between Airdrie Furnace and the Ohio river, and these are of a size uniform on Green river—one hundred and forty-five feet long by thirty-six feet wide.

THE FURNACE.

The furnace was built in 1855–'56. It has an iron shell stack, resting upon a masonry base, twenty-six and a half feet square by twenty-one feet high. The outside diameter of the shell is twenty-three feet.

The internal dimensions of the furnace are as follows: height fifty feet, diameter of bosh seventeen feet, height to bosh twenty-four feet (bosh cylindrical for six feet), diameter of throat eleven feet. The hearth is four feet high (elliptical in shape), seven feet four inches by (about) five feet.

The furnace is entirely open-topped, having no facilities for saving the gases, and requiring separate firing for both boilers and hot-blast.

There are two hot-blast ovens of the old-fashioned pistol-pipe pattern, with thirty-four pipes in each oven, ten curved pipes on each side, with seven straight at each end. The pipes are eight feet long, elliptical in cross section, nine by eighteen inches, with diaphragm through the center of each.

There are four boilers, each forty inches in diameter by twenty-eight feet in length, each boiler having two flues. The engine is vertical, with direct connection between the steam and blast cylinders, and also connected with a heavy walking beam and fly-wheel, the walking beam working with a counterpoise at one end.

The steam cylinder is twenty inches in diameter, and nine feet stroke; the blast cylinder six feet ten inches in diameter, stroke same as steam cylinder.

The engine-house is a splendid stone structure, built of a fine free stone, which occurs at the furnace. Everything about the furnace is constructed in the most thorough and durable manner.

The top of the furnace is about the level of the No. 11 Coal, to be hereafter described, and the ore and coal from the No. 12 seam were brought to the furnace mouth through a tunnel cut in the No. 11 Coal.

The engine is in good order and well preserved.

The furnace proper stands perfectly sound, and could, in a very brief time, be put in condition to go into blast; but among the buildings attached thereto the lapse of the many years since they were in use has not been without its effect, so that repairs to both buildings and hot-blast apparatus will need to be made before they can be used again.

THE PROPERTY.

The Airdrie Furnace property consists of about 17,000 acres of land in Muhlenburg county, Kentucky. This land is not all in one body, but lies in various sized lots, ranging from 500 to

5,000 acres. The greater portion of the estate lies within a short distance of the furnace; but one tract of about 5,000 acres—the old Buckner Furnace property—is about five miles from Greenville, the county seat of Muhlenburg county, and fifteen miles from Airdrie. Upon this tract, if all reports be true, there are extensive beds of iron ore, as well as some of the lower coals, one of which, said to be four feet thick, was mined and coked for use at the old Buckner Furnace. The situation is such, however, being five miles from the railroad at Greenville, that for the present, at least, the minerals of this tract cannot be rendered available.

We come then to the examination of the property adjacent to the furnace. A geological section showing the number and position of the coals here is given in the third volume of the Kentucky Geological Reports, first series, page 24. This section was obtained in sinking a shaft at the furnace, and the measurements are therefore probably much more accurate than those usually obtained by boring. In reproducing the essential parts of the section, and describing the coals, the numbers assigned to them in the first series Geological Survey Reports will be used provisionally, for the reason that they are best known by these numbers, and that, although they have been discarded by the present Survey, the final nomenclature has not yet been decided upon.

We have, then, at this place the following coals:

I. Coal No. 12, two feet thickness of clear coal, then two feet of brashy coal. Resting upon this is a bed of slaty carbonate of iron, which sometimes contains a small amount of carbonaceous matter, and is called a Black-band iron ore. This ore ranges from four to fourteen inches in thickness, with an average of perhaps five or six. Its chemical constitution will be referred to hereafter.

II. Twenty-one feet below Coal No. 12, resting immediately under a hard, blue limestone, is Coal No. 11, six feet thick, in three members, each about two feet in thickness, with a parting of one to two inches of pyritiferous shale between each member. This coal is about sixty-five feet above Green river.

III. Below the level of Green river, and eighty-four feet under Coal No. 11, is Coal No. 9, five feet thick. This is the same coal as that mined so extensively for the Louisville market along the line of the Louisville, Paducah and Southwestern Railroad. Little is known of its quality here, but it is safe to suppose that it does not vary greatly from that along the railroad.

IV. There are one or two thin coals below this, but it is not until a depth of three hundred and forty-one feet below No. 9 is reached that another coal of workable thickness occurs. This is called No. 5 by Dr. Owen, and is three feet six inches thick. If the report of the miners who sunk the shaft, and of others who were employed at the furnace, is to be believed, this coal is of most excellent quality. A drift was run, and considerable coal taken out and used under the boilers with great success.

We see, therefore, that there are here, including the No. 12 Coal, which can be profitably worked with the overlying iron ore, no less than four coals of workable thickness.

QUALITY OF THE COAL.

Of the quality of No. 5 and No. 9 Coal at this place, we of course know nothing, for it was impossible to obtain samples for analysis. Samples of the No. 11 coal were obtained from the mine at Paradise, adjoining the Airdrie property. They were taken with great care from a number of rooms in the mine, in order to obtain as nearly an average as possible, representing the coal as actually mined and shipped. It is a brilliant black, firm coal, with comparatively little fibrous coal or mineral charcoal. It cleaves readily into large rectangular blocks in mining. There is considerable pyrites mingled with it in an increasing ratio from the top to the bottom, the upper member carrying the least. A sample was taken from each member. The following analyses are by Dr. Peter and Mr. Talbutt, chemists of the Survey:

ANALYSES OF NUMBER ELEVEN COAL, PARADISE MINE.

	Upper.		Middle.		Bottom.	
Specific gravity	1.274		1.326		1.331	
Moisture	3.60		4.10		4.20	
Volatile combustible matter.	38.70		35.90		36.10	
Fixed carbon	53.70	coke 57.70	53.60	coke 60.00	50.50	coke 59.70
Ash	4.00		6.40		9.20	
Total	100.00		100.00		100.00	
Sulphur	3.158		4.394		4.573	

It will be seen from the above that while an extremely good coal in the matter of freedom from water and ash, yet there is a very considerable per centage of sulphur present. It is, however, an excellent household and steam coal, and is held in high repute wherever it has been tried. Large quantities are sent from the Paradise mines to Bowling Green, where it is used for domestic purposes and by the railroad, and it is there rated higher than any other coal from Green river.

The No. 12 *Coal.*—As it was in the expectation of using this coal raw for fuel that the furnace was built, and as it was actually so used during the short campaigns of the furnace, it became a matter of considerable importance to obtain a perfectly average representative sample for analysis.

The attempt to obtain such a sample was only partially successful. The old entries by which the coal was worked have fallen in, so that it was impossible to get at the face of the coal where a sample from a number of places could be taken.

A shaft was, therefore, sunk through the coal near one of the entries, and an average sample taken. Another was taken from a pile of several thousand bushels which lies at the mouth of one of the old drifts, where it has been exposed to the weather for seventeen years. Although these must both represent the coal with a certain degree of accuracy, yet at both places it had been to a certain extent exposed to the weather, and may have absorbed water and parted with some sulphur.

The fact that the coal is quite "fat," however, containing much bituminous matter, tended to preserve it from the action of the weather. In the interior of the pile of coal at the entry many pieces were found only very slightly affected by its protracted exposure.

It is a deep black coal, showing little pyrites, and quite bituminous, too much so apparently to be successfully used alone raw in the blast furnace. Of the following three analyses the first was made by Dr. Peter, and published in the fourth volume of Kentucky Geological Reports, first series, page 230. Of the character of the sample and by whom taken I am ignorant. The second and third are by Dr. Peter and Mr. Talbutt, from average samples taken by myself. The second is the weathered coal from the stock-pile; the third from bottom of shaft near entry No. 4.

ANALYSES OF NUMBER TWELVE COAL, AIRDRIE FURNACE.

	I.		II.		III.	
Specific gravity	1.593		1.332		1.278	
Moisture	7.06		4.70		3.60	
Volatile combustible matter	30.84		30.60		31.40	
Fixed carbon	58.70	coke 62.10	58.80	coke 64.70	58.50	coke 65.00
Ash	3.40		5.90		6.50	
Total	100.00		100.00		100.00	
Sulphur	0.789		1.455		1.438	

A remarkable resemblance will be noticed between analyses two and three, showing that they have weathered very similarly; but the coal of No. 2 has absorbed more water and lost some of its volatile combustible matter. They show this to be a coal of very good quality, with neither sulphur nor ash sufficient to seriously injure it. It is so bituminous that it did not work well raw in the furnace, and after three unsuccessful trials it was decided to use it coked. A large amount of coke, several thousand bushels, was made; but the furnace was never started again, and it now lies on the stock bank, some of it good looking coke yet, after the rain and snows of seventeen years have fallen upon it. It is difficult to tell what the quality of it was when first made, and a sample taken from this pile does not fairly represent the coke that can be made from the coal; but it was regarded as matter of sufficient interest to be worth an analysis. I accordingly selected from the least weathered of the coke a sample for analysis, which is here given. The coke was made in open heaps, and therefore is not as firm and dense as it would be if coked in close ovens:

Moisture expelled at 212°	7.50
Moisture expelled at red heat	4.20
Fixed carbon	82.90
Ash	5.40
Total	100.00
Sulphur	0.642

The composition of the ash is as follows:

Silica and silicates	4.32
Alumina, oxide of iron, and manganese	.48
Lime	.33
Magnesia	.18
Phosphoric acid	.08
Total	5.39

As was to be expected, the coke has absorbed a very considerable per centage of water; but the amounts of both sulphur and ash are small.

THE IRON ORE.

Above the No. 12 Coal, already referred to, is a hard, dense, slaty carbonate, often containing fern leaf impressions between its cleavage planes. The amount of bituminous matter shown by analysis is small, and probably adheres to it from the associate shale and coal. It contains occasional specks of pyrites large enough to be easily seen by the unassisted eye. Its appearance is decidedly against it, and it seems to be much leaner than it really is.

The same difficulty was experienced in obtaining a fair average sample of the ore as with the No. 12 Coal. A sample was obtained from the same shaft, sunk to reach the coal near the old No. 4 entry, but it was so near the surface that the ore had been altered to a limonite. At this place, too, it seemed to be less silicious than usual, and the average, of course, was taken from only a limited amount of ore. Another sample was taken from a pile of unroasted ore lying near the mouth of the entry, where it has been exposed to the weather for seventeen years.

Still another sample was taken from a large pile of roasted ore, which had undergone a like period of exposure since roasting. In all of these there is a possibility that the ore is a little richer in iron and more free from sulphur than will be found to be the case when it is reached at a place where it is wholly unaltered; for the exposure to the air has a most beneficial effect in peroxidizing the iron and removing the sulphur.

The analyses by Dr. Peter and Mr. Talbutt are as follows:

	1.	2.
Peroxide of iron	63.048	59.810
Alumina	5.290	2.972
Brown oxide of manganese	.090	.720
Carbonate of lime	.680	. . . . .
Lime	. . . . .	2.263
Magnesia	.930	4.270
Phosphoric acid	.147	.223
Sulphur	.044	.065
Combined water	12.430	.206
Silica and insoluble silicates	17.250	29.880
Total	99.909	100.409
Specific gravity	3.246	3.652
Metallic iron	44.133	41.867
Phosphorus	.064	.097

No. 1. Ore from bottom of shaft near No. 4 entry.

No. 2. Roasted ore from the stock-pile, weathered seventeen years since roasting.

The above ores are both altered from the carbonate; one by the slow natural process of oxidation, the other by the process of roasting.

The analyses of the carbonate ores:

	1.	2.
Carbonate of iron	47.810	59.344
Peroxide of iron	9.054	4.180
Alumina	5.205	2.290
Carbonate of manganese	.797	2.017
Carbonate of lime	3.740	3.390
Magnesia	7.180	7.149
Phosphoric acid	.179	.428
Sulphur	.094	.246
Carbonaceous matter and water	8.788	4.071
Silica and insoluble silicates	17.010	16.280
Total	100.099	100.609
Potash	.....	.286
Soda	.....	.322
Specific gravity	3.376	2.959
Metallic iron	29.418	31.598
Phosphorus	.078	.186

No. 1. Average sample from the stock pile, where the ore had weathered seventeen years.

No. 2. Analysis by Dr. Peter, published in volume three, page 337, of the first series Kentucky Geological Reports, of "Black-band ore, roof of upper coal', Airdrie Furnace."

From the foregoing analyses the following conclusions are drawn:

First. The No. 11 Coal, while a fine domestic and steam-producing fuel, contains too much sulphur to be used in the manufacture of iron, without a previous preparation by washing and coking.

That this could be successfully done there is little doubt. The strength and density of the coke might not be equal to the best, but it would be a fuel of fair quality; such as could, it is believed, be used successfully in the manufacture of iron.

Second. The No. 12 Coal is an excellent fuel, on account of its small per centages of sulphur and ash; but the former experience of the furnace seems to prove conclusively what the appearance of the coal indicates, that it is too fat to use raw in the furnace, and should be coked. The amount of sulphur is so small that the coal can be coked without previous preparation, to free it from sulphur, and it will probably produce a superior coke; this, however, can only be demonstrated by actual trial on a large scale.

Third. The ore contains enough iron and is sufficiently free from injurious mixture to be safely used to a certain extent; but it will probably prove necessary to use other ores with it.

It is not unlikely, as already stated, that the analyses represent the ore as somewhat better than it really is, and that it will be found on trial, when used alone, to make a low grade of iron. There is, furthermore, the fact that, while both the coal and ore have to be mined together in order to be cheaply obtained, the output of coal for a given area will be more than twice as much as is required for the reduction of the ore from the same area, assuming from the general testimony that the coal will average two feet in thickness and the ore six inches. Of the coal, with a specific gravity of 1.33 and a thickness of two feet, each acre of land will contain 3,300 tons of 2,240 pounds each.

Of the ore, with a specific gravity of 3.25, and six inches thick, each acre will contain 2,015 tons. The ore will probably not yield in the furnace more than an average of twenty-eight or twenty-nine per cent., thus requiring for the production of one ton of iron three and a half tons of the raw ore. For the reduction of this amount of ore only from two to three gross tons of coal will be required, probably not exceeding an average of two and a half tons.

The coal from one acre of land will, therefore, be sufficient for the reduction of more than two and a fifth times as much ore as is produced from the same area. The necessity, then, of looking elsewhere for a partial ore supply is evident.

The situation of Airdrie Furnace is one remarkably favorable for the facilities with which ores from a number of regions can be cheaply laid down at the furnace. It can command, at very reasonable rates for freight, the following ores:

(*a*) Coal measure ores from Green river valley.
(*b*) Limonites from the Cumberland river region.
(*c*) Specular ores from Missouri.

(*a*) Coal measure ores from the Green river valley. There are, in a large number of places in the valley of Green river, ores of workable thickness and apparently considerable area; but they are as yet generally undeveloped, and frequently so far from the river or other means of transportation that they cannot be rendered available without the expenditure of considerable sums to provide such means of transportation. To this class belong the ores of the Buckner Furnace tract, already referred to. These must some day be developed and used at the furnace; but for the present they are inaccessible. They comprise both slaty carbonates or Black-band, and fossiliferous ores.

One locality was visited where is an exposure of eight or ten inches of the Black-band ore, and a sample for analysis selected. The ore from which it was taken had been exposed to the weather for thirty years or more.

The following is the analysis by Dr. Peter and Mr. Talbutt:

Carbonate of iron	42.950
Peroxide of iron	29.618
Alumina	2.454
Carbonate of manganese	1.083
Carbonate of lime	2.490
Carbonate of magnesia	4.828
Phosphoric acid	.083
Sulphuric acid	1.596
Carbonaceous matter and loss	5.868
Silica and insoluble silicates	9.030
Total	100.000
Metallic iron	36.916
Phosphorus	.036
Sulphur	.638

In Edmonson county, on the north side of Green river, between Bear Creek and Nolin river, is an extensive and valuable deposit of oölitic ore; but it is, where best developed, some six miles from Green river, and it cannot be hauled to the river cheaply enough to compete with ores from other places lower down. It is of excellent quality, and can be mined quite cheaply, and, if accessible, would be one of the most available ores. I append analysis, by Dr. Peter and Mr. Talbutt, of ore from a bank at the head of Beaver Dam Branch of Bear Creek. Average sample by Prof. N. S. Shaler:

Peroxide of iron	52.926
Alumina	4.792
Brown oxide of manganese	.210
Carbonate of lime	.180
Magnesia	.425
Phosphoric acid	.355
Sulphur	.057
Combined water	10.400
Silica and insoluble silicates	30.589
Total	99.934
Metallic iron	37.048
Phosphorus	.155

In Butler county, near the mouth of Little Reedy Creek, from one and a half to two miles distant from Green river, on the James E. Taylor farm, is a deposit of ore which shows at the outcrop three feet thick. It was only seen at one place, and little or nothing is known of its horizontal range. It has never been worked. An average sample was taken by Mr. J. R. Proctor, who first discovered it, and analyzed by Dr. Peter and Mr. Talbutt, with the following result:

Peroxide of iron	48.049
Alumina	8.171
Brown oxide of manganese	.140
Carbonate of lime	.540
Magnesia	.195
Phosphoric acid	.345
Sulphuric acid	.473
Combined water	9.750
Silica and insoluble silicates	31.900
Total	99.563
Metallic iron	33.634
Phosphorus	.150
Sulphur	.189

It is a silicious, somewhat oölitic limonite, altered from the carbonate; and as it occurs in shales, with a high hill above it, it will probably be soon found as the blue carbonate.

Its situation is such that it can be very cheaply placed in boats, on the slack-water of Green river, about seven miles above the lock at Woodbury. Should it be found, on closer examination, to retain its thickness, and extend over a considerable area, it can be mined very cheaply.

A reasonable estimate of its cost at the furnace, provided the above conditions hold, would be:

	Per ton.
Mining and royalty	$1 75
Hauling to river and loading on barges	75
Freight on Green river	1 25
Unloading at furnace	25
Making the total cost	$4 00

Two of these items, the freight on Green river and the hauling to the river, might be considerably reduced. It is probable that three dollars or three dollars and fifty cents would be a minimum cost at the furnace.

In Muhlenburg county, on Mud river, on land belonging to Jeremiah M. Hope, is a deposit of ore which, over a limited area, shows the unusual thickness of twelve to fifteen feet. The ore is exceedingly fossiliferous, partly a limonite and partly an unaltered carbonate. The upper portion of the ore is somewhat lean and silicious; the middle and lower portions of the bed are of fine quality.

The following analyses by Dr. Peter and Mr. Talbutt show the character of the ore:

	1.	2.	3.
Peroxide of iron	46.866	60.492	18.374
Carbonate of iron	. . . . .	. . . . .	26.643
Alumina	5.930	7.075	6.548
Brown oxide of manganese	.103	.360	a trace.
Carbonate of lime	2.535	1.980	13.430
Magnesia	1.073	1.550	5.698
Phosphoric acid	.179	.083	.211
Sulphur	.059	.074	.074
Combined water	9.550	12.530	6.792
Silica and insoluble silicates	33.530	15.560	22.230
Total	99.825	99.674	. . . . .
Metallic iron	32.806	42.344	27.136
Phosphorus	.077	.032	.092

1. Sample, not carefully averaged, of limonite from the upper portion of the deposit.

2. Average sample of the limonite of the lower and middle portions of the deposit.

3. Average sample of the blue carbonate ore of the lower part of the deposit.

This ore seems to be in a regularly stratified deposit, but it only retains its unusual thickness over an area of perhaps 1,200 square yards. It is found at another locality, one third of a mile distant, on the opposite side of the ridge, two and a half feet thick.

The distance of the principal deposit from the head of slack-water, on Mud river, is four miles. Over this distance the ore would have to be wagoned, at a probable cost of one dollar and fifty cents per ton. The distance from the head of navigation, on Mud river, to Airdrie, by water, is about twenty miles, and in that twenty miles one lock to be passed. The cost of freight would be about seventy-five cents per ton. The ore can be mined quite cheaply, as very little stripping will be required for some time. One dollar and twenty-five cents will probably be sufficient to cover the cost of mining and royalty. The cost of this ore would therefore be:

	Per ton.
Mining and royalty	$1 25
Hauling to river	1 50
Freight to Airdrie	75
Unloading at furnace	25
Total	$3 75

By the purchase of the deposit and the use of their own barges by the owners of the furnace, this cost might be reduced to three dollars, or even less.

In Muhlenburg county, near Greenville, on the farm of Mr. Dabney Martin, some three miles from the Louisville, Paducah and Southwestern Railroad, is a bed of quite pure limonite ore. It is only eight inches thick, but is so situated that it could be mined over a large area, as the stripping above it would not be deep. It is of excellent quality. The analysis is as follows:

Peroxide of iron	69.546
Alumina	3.914
Brown oxide of manganese	.230
Carbonate of lime	.480
Magnesia	.921
Phosphoric acid	.115
Sulphur	.086
Combined water	11.250
Silica and silicates	12.730
Total	99.272
Metallic iron	48.882
Phosphorus	.050

This ore would cost, delivered on the cars at Greenville, three dollars per ton; freight from Greenville to Rockport, one dollar and fifty cents; hauling and freight from Rockport to Airdrie, fifty cents—making the cost of the ore at the furnace five dollars per ton, a price which renders its use at present out of the question.

(*b*) Limonites of the Cumberland river region. The ores of this region are too well known to need especial description. They are cherty limonites found in the clays on the sub-carboniferous limestone, in unstratified and irregular but extensive deposits. They vary greatly in quality at every deposit, and great care is required in mining to prevent the cherty ore from becoming mixed with the better quality. They yield from thirty-five to fifty per cent. of the iron, and even higher when free from chert. There are numbers of these deposits in Lyon county, close to the line of the Louisville, Paducah and Southwestern Railroad. I visited some of these and obtained samples for analysis:

	1.	2.	3.	4.
Peroxide of iron	59.370	70.518	66.117	69.412
Alumina	1.622	.045	1.064	not est.
Brown oxide of manganese	.090	.190	.170	.170
Carbonate of lime	.170	.090	.090	.140
Magnesia	.100	a trace.	a trace.	a trace.
Phosphoric acid	.179	.275	.434	.313
Sulphur	.212	.045	not est.	a trace.
Combined water	8.400	9.850	9.800	9.550
Silica and insoluble silicates	30.000	18.910	22.330	20.500
Total	100.053	99.923	100.005	100.085
Metallic iron	41.559	49.363	46.282	48.588
Phosphorus	.077	.120	.189	.144

These ores are all from the old Suwanee Furnace lands, in Lyon county, and the samples were taken to represent, as nearly as possible, the average character of the ore of each deposit, chert and all. All of the ore could be picked so as to give a much better average, and it would be necessary to do so in shipping.

No. 1. Ore from "Big Showing" bank, Suwanee Furnace property, Lyon county.

No. 2. Ore from bank close to the furnace, Suwanee Furnace property, Lyon county.

No. 3. Ore from bank at railroad cut, Suwanee Furnace property, Lyon county.

No. 4. Ore from Iron Mountain bank, Suwanee Furnace property, Lyon county.

It would be safe to estimate that these ores can be relied on to yield forty-five per cent. of iron, where properly sorted before shipment.

These deposits are situated about eighty miles from the crossing of Green river at Rockport.

Parties stand willing to-day to deliver these ores on the cars at two dollars and fifty cents per ton. The Louisville, Paducah and Southwestern Railroad will transport, in small quantities, from Lyon county to Rockport for one dollar and fifty cents per ton, and will take large quantities at much less rates. It is probable that on a regular contract the rates would not exceed one dollar or one dollar and twenty-five cents per ton. The expense of loading into barges at Rockport, towing to Airdrie (four miles) and unloading, should not exceed fifty cents per ton. By the erection of a proper chute or tip at Rockport this could be reduced nearly one half.

Assuming the maximum rates for freight, the cost of Lyon county ore at Airdrie would be:

	Per ton.
Ore delivered on cars	$2 50
Freight to Rockport	1 25
Handling and towage to furnace	50
Total	$4 25

This could be reduced by making large contracts and some expenditure for a dock at Rockport; but this estimate, like all the others, is made on a basis of the purchase of the ore without the investment of any capital. With such investment, four dollars per ton would safely cover the cost of a ton of ore at the furnace.

(*c*) The specular ores of Missouri. These well-known ores are known under two classes, the Iron Mountain ore and the Central Missouri ores. There is not a great deal of difference in their quality. They are all rich, yielding from sixty to sixty-seven per cent. of iron. The Iron Mountain ore has a little the largest per centage of iron, and is of the most uniform quality. It averages sixty-five to sixty-seven per cent. of iron; the Central Missouri ores from sixty to sixty-five. Iron Mountain ore is now worth in St. Louis seven dollars per ton; Central Missouri ores, six dollars. These ores can be brought in barges directly from St. Louis to the furnace, or they can be shipped to Evansville by rail, and from there to the furnace in barges. In either case, the cost for transportation from St. Louis should not exceed two dollars and fifty cents to three dollars per ton; thus making the cost of the Missouri ores nine dollars and fifty cents to ten dollars per ton at the furnace for Iron Mountain ore, and eight dollars and fifty cents to nine dollars for Central Missouri.

THE AVERAGE COST PER TON OF IRON

for each of the two classes of ore available to Airdrie Furnace, based on the foregoing estimates, which are certainly large enough in each case to be almost called maximum estimates, would be:

3	tons Green river ore, at	$3 75 per ton	$11 25
2¼	tons Cumberland river ore, at	4 25 "	9 56
1½	tons Iron Mountain, at	10 00 "	15 00
1⅔	tons Central Missouri, at	9 00 "	15 00

The Cumberland river ores, therefore, are considerably the cheapest that can be obtained at present without the outlay of considerable additional capital.

Their richness is such as to add another considerable advantage to them over ores with a less per centage of iron, for they are proportionately more economical to use in the furnace, as they require less fuel for their reduction.

In a time of ordinary prosperity of the iron market, any of the other ores can be profitably and successfully used.

Limestone for use as flux will have to be brought from upper Green or Barren river. It occurs at many places there in heavy deposits immediately on the bank of the stream, and can be quarried and placed in barges very cheaply. It is probable that seventy-five cents per ton will cover the cost of the limestone at the furnace.

The limestone required will not exceed twenty-five per cent. of the ore used, and may be less, as the Black-band ore, although lean, contains a considerable proportion of lime and other bases and will partly flux itself. There is a limestone four to five feet thick forming the roof of the No. 11 coal; but it is somewhat earthy, and at places quite sulphurous. It was tried during the former campaign of the furnace, but soon abandoned, and its place supplied with limestone from the mouth of Gasper Creek, on Barren river. This, as will be seen by the following analysis, is a nearly pure limestone of excellent quality:

Alumina and oxide of iron	0.917
Carbonate of lime	93.020
Carbonate of magnesia	2.088
Phosphoric acid	.243
Sulphuric acid	.604
Silica and insoluble silicates	2.760
Water and loss	.368

We have shown the number of alternatives possible to the furnace in the matter of an iron ore supply: let us look for a moment at the corresponding advantages for fuel.

Suppose No. 12 Coal should prove too thin to work, and the No. 11 not of as good quality as needed. The great shaft stands open, the boiler, winding drum, and engine for operating it are ready to be put in operation, in a short time, to give access to the two coals below the drainage. Suppose on trial neither of these proves a suitable fuel for iron making; Airdrie Furnace is only twenty miles by water from the well-known Mud River mines, the coal from which is among the best (if not the best) in the Green River country. That this will make iron raw, there is little doubt. A barge load of it was taken to St. Louis a few years since and tried very successfully in one of the Kingsland (now Vulcan) Company's furnaces. These mines are on slack-water, and can be reached from Airdrie at all times of the year.

The excellent quality of coal can be seen from the following analysis by Dr. Peter and Mr. Talbutt. The sample was a carefully taken average from all parts of the seam by myself:

MUD RIVER COAL.

Moisture	3.80	
Volatile combustible matter	32.70	
Fixed carbon	58.00	Coke 83.50.
Ash	4.90	
Sulphur	1.929	
Specific gravity	1.221	

Yet another alternative remains to Airdrie Furnace. Its situation on the bank of Green river is such that it can be cheaply and easily supplied with charcoal in case the manufacture of charcoal iron should be desirable.

Large portions of the valley of Green river are an almost unbroken forest, both above and below the furnace. Timber for the manufacture of charcoal can be purchased along the river at very small prices, and sometimes can be had for the clearing. This can either be rafted to the furnace, and there made into charcoal in ovens, or it can be charred on the ground and carried to the furnace in barges. In either case it can be furnished there cheaply enough for the manufacture of charcoal iron at a profit in the ordinary stage of the market.

We see, therefore, that Airdrie furnace is so fortunately situated as to be able to command, at reasonable prices, at any of which, in the ordinarily prosperous condition of the iron market, iron can be made at a profit:

Ore from four different regions.

Coal from four different beds at the furnace.

The Mud River coal.

Charcoal.

Such advantages as these, it can be truly said, are unsurpassed, and they render it certain, beyond reasonable doubt, that, with proper management, Airdrie Furnace can be made one of the most successful in the country.

Having thus considered in detail the resources of this property, and seen the remarkable advantages it possesses for obtaining fuel and cheap and varied supplies of ores, the question naturally presents itself: why, then, with all these advantages, was the furnace no more successful on its former trial? This is a serious and important question, for the reproach of failure laid against an enterprise of this kind outweighs many advantages.

Into the answer a number of reasons enter, and to render them properly understood it will be necessary to go into the history of the former campaign of the furnace in some detail, and to refer to the management of the enterprise in language which is unmistakable, although it may seriously reflect upon the business sagacity of some persons once connected with it who are no longer living. It should be premised that the information upon which the following account is based was obtained partly from the books of the furnace and partly from men who were on the ground, connected with the furnace in various capacities.

The enterprise seems to have been conceived by its proprietor in a spirit in which benevolence, national pride, and the desire for a profitable investment, were strangely mingled. Being a Scotchman, and having some knowledge of iron manufacture as practiced in Scotland, he not unnaturally believed men of that nationality to be the most competent and desirable persons to conduct establishments for iron making.

He therefore committed from the beginning the serious mistake of employing almost exclusively newly-arrived foreigners, men who, however competent at home, were without any knowledge of American prices and metallurgical practice, or experience with American ores and fuel.

Having found what was firmly believed to be the equivalent of the celebrated Scotch Black-band iron ore, and an associate coal which it was thought could be used raw in the furnace, he proceeded to erect a furnace modeled after the Scotch pattern. He brought over large numbers of Scotch miners and furnace men, and employed them almost exclusively; giving them to understand, it is reported, that it was to improve their condition, rather than in hopes of great returns, that he had made the investment. He employed as superintendent and manager an uneducated, dissipated Scotchman, a man wholly unfit to fill so important and responsible a position, and to him he gave almost entire charge of the whole enterprise, often not visiting the property for months at a time.

Under such conditions, it is no wonder that there was mismanagement, and that ill-advised expenditures were made.

For three years, while the slow process of development was going on, the furnace and machinery erected, entries driven, and the great shaft, five and a half by eighteen feet, sunk to a depth of four hundred and thirty feet in search of a mythical ore (known to exist fifteen miles distant and nowhere between), the proprietor continued uncomplainingly to increase his investment.

At last the furnace was started. It ran a few days very unsuccessfully, producing iron of a poor quality and in small amount, when an accident to the boiler compelled it to be blown out.

Repairs were made in due time and the furnace again started. The working was no better than before, and the iron not improved in quality or quantity. In twenty-two days from the time of starting the saddle-plate of the walking-beam broke, disabling the engine and compelling the furnace to be shoveled out. Again it started, and again, after a short run, no more successful than the last, an accident happened to the engine, the cast-iron shaft of the fly-wheel broke, and once more the furnace was shoveled out.

In all three of these unfortunate campaigns the furnace was not in blast altogether more than six weeks or two months.

After the last blast the manager concluded that the coal did not work well raw, and so made a large amount of coke from it to be tried at the next blast, but the next blast never came; the proprietor's patience was exhausted; he stopped operations entirely, discharged his men, and shut up the mines and furnace.

Since that time (November, 1857) the furnace has never been in operation. The No. 11 Coal has been worked largely for shipment to the Southern market, but beyond that the property has been lying idle and unproductive.

The closing of the furnace at that time was a mistake no less serious than some committed in starting it. The manager was beginning to learn, by the only method by which a so-called practical, uneducated man can learn—his own dear-bought experience—that American ores and fuel are not exactly like the Scotch, and that different practice is required for their treatment. Had he been allowed to go on, using coke for fuel, it is not unlikely that his next campaign would have proved much more successful.

It can be truly said that the furnace has never been subjected to a fair trial. A total campaign of six weeks or two months, divided into three short blasts, affords no fair basis for judgment as to the merits of furnace, fuel, or ore.

The iron made at the furnace was of notoriously poor quality. In order to ascertain to what cause this was due, three samples were procured from the iron remaining at the furnace, the analysis of which, by Dr. Peter and Mr. Talbutt, are herewith appended. The samples are all from a grade of iron variously known as silver gray, burnt iron, or glazed pig. It was impossible to procure samples of any other grade of iron. It is a fine-grained, light-colored iron, extremely weak and brittle.

The analyses are as follows:

	I.	II.	III.
Iron	86.645	85.863	86.842
Graphitic carbon	.900	.400	.780
Combined carbon	2.080	2.570	2.070
Silicon	7.704	7.747	8.614
Manganese	.571	.696	.355
Aluminum	.202	.274	.136
Calcium	.072	.112	.112
Magnesium	.035	.017	.056
Sulphur	.127	.227	.173
Phosphorus	.253	.509	.122
Total	98.589	98.415	99.260

Slag undetermined.

It will be seen that the proportion of sulphur and phosphorus is quite high in No. II, but it is probable that the poor quality of the iron is due more to the excessive amount of silicon than to any other cause.

The attempt was made to produce a No. 1 foundry iron by working the furnace hot, and the result was, that with a hot working of the furnace much silicon was reduced with the iron, and rendered it very brittle or "cold-short." Had the manager been content to burden his furnace for a "mill iron," working colder, it is probable the product would have been of much greater strength, although, as already stated, it is not unlikely that the Airdrie ore worked alone will always have a tendency to produce a low grade of iron. Hence, the necessity for some supply of ore from other sources.

That Airdrie Furnace, with some alterations and proper management, can be made to produce iron of good quality, and at a very low price, there is little doubt. In order to this, however, it will be advisable to considerably alter and modernize the furnace. It should be raised ten to fifteen feet in height, in order to give it dimensions better adapted to economical working, and a closed top and down-takes to carry the waste gases to boilers and hot blast added. The position of the boilers will have to be altered, the smoke-stack raised, new hot-blast ovens erected, or the present ones changed, and a new casting-house built. It will be also advisable to erect coking-ovens; and, in case the No. 11 Coal is used, washing machinery will be required in addition.

The total amount required to make all the needed changes, open the mines, and put the furnace in operation, will not exceed $60,000.

These changes made, Airdrie Furnace can produce iron, considering its nearness and cheapness of transportation to market, for a less price per ton than any other furnace in Kentucky.

We have already shown the cost at which ore and limestone can be supplied at the furnace. We have now to consider the cost of fuel, when we will have the material in hand to prove the above statement.

Mining the coal and the ore together, the No. 12 Coal can be mined for one dollar per ton, the ore for one dollar and seventy-five cents.

Allowing fifty cents per ton as the cost for handling and mine expenses, &c., we have the cost of the coal one dollar and a half per ton. Three tons of coal will make two tons of coke, at a cost for coking of fifty cents per ton. Allowing the large consumption of two tons of coke to the ton of iron, and using one and one eighth tons of Cumberland river ore to one and three fourths tons Airdie ore, the cost per ton of pig iron at the furnace would be:

Two tons of coke, at $2 75 per ton	$5 50
One and three fourths tons of Black-band ore, at $1 75 per ton	3 06
One and one eighth tons Cumberland river ore	4 78
Roasting two and three fourths tons of ore, at twenty cents per ton	55
Two thirds of a ton of limestone	50
Labor and superintendence	3 50
Sundries	1 00
Total estimated cost per ton	$18 89

The iron can be put in market for from two dollars to three dollars per ton additional. Even supposing all the odds against the furnace, and that the iron produced is of a low grade, yet there would be a profit in it, even in the present fearfully depressed condition of the iron trade.

The demand of the future is for cheap iron. The days of high-priced iron have gone, not to return for months to come, if ever; and, in the struggle for existence, only those furnaces which are favorably located and carefully managed can survive. For such as can produce iron economically and cheaply, there will always be a profitable market, and only for those.

To this class Airdrie Furnace certainly belongs.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

ON THE GEOLOGY

OF

HANCOCK COUNTY,

BY P. N. MOORE.

STEREOTYPED FOR THE SURVEY BY MAJOR, JOHNSTON & BARRETT, YEOMAN PRESS, FRANKFORT, KY.

ON THE GEOLOGY OF HANCOCK COUNTY.

SURFACE FEATURES.

Hancock county is one of the smallest counties of Western Kentucky. It has an area of 168 square miles. Its northern boundary is the Ohio river, which, while flowing around this county, makes two large bends toward the north, so that the point where the county line comes to the river at the mouth of Blackford creek, on the western edge of the county, is further north than the point where the eastern line leaves it below Cloverport. Breckinridge county joins Hancock on the east, Ohio lies on the south, and Daviess on the west.

The principal stream of Hancock county is Blackford creek, which drains a larger part of its area than any other, and forms the county line on the west for a considerable distance. Yellow, Lead, and Indian creeks are other streams flowing into the Ohio river, which drain the northern part of the county, while the head branches of Panther creek drain the extreme southeastern corner, beyond the branches of Blackford creek.

This county does not present a great variety in its topographical features. The highest part of the county is in the extreme southeastern corner, at the head of Panther creek and Tar Fork, where the hills reach a height of more than 400 feet above the Ohio river. From here there is a gradual descent towards the west or northwest, until the hills of the main dividing ridges rarely rise higher than 200 feet above the river, while the general level of the country is much less.

Accompanying this decrease in height, toward the west, there is a change in the character of the hills. The slopes are not so steep, and there is a much larger proportion of level or gently rolling land. Toward the heads of the streams, in the southeastern corner of the county, the hills are steep and the valleys narrow. The type of topography here seems to be produced by frequently alternating shales and sandstones, no one bed of which is of any great thickness or prominence. It is also partly due to the fact that, lying so near the heads of the streams, erosion has not been so great, as the amount of water in the streams is only that which has fallen upon it, and not the accumulation from above.

Near the Ohio river, in the upper part of the county, above Hawesville, the Conglomerate sandstone is present in considerable thickness, and gives rise to a topography, the principal features of which are comparatively even ridges, with gorge-like valleys and steep cliffs.

The Big Clifty or Tar Spring sandstone, at the base of the Chester Group, is also so heavy and coarse that it produces nearly the same result in the extreme eastern edge of the county, where the Conglomerate does not occur.

The heavy sandstones above the Conglomerate continue this type of topography, though with much less prominent features, and steadily growing less and less so, as far to the west as Hawesville, and for five or six miles back from the river. From here to the southern edge of the county these sandstones grow thinner and less prominent, and the hills lower, with more gentle slopes.

The topography of the western part of the county presents even less variety and fewer prominent features than the eastern portion. The hills are lower, and, especially toward the Ohio river, more gently sloping, and the valleys are wider. The streams, except at their heads, are sluggish, and have wide flat bottoms. In fact, the bottom lands of the Ohio river and the principal creeks form, probably, over one half the total area of the western part of Hancock county.

The prevailing rocks, as indicated by the topography and the exposures, which, however, are rare, are shales or shaly sandstones. On some of the higher ridges a coarse, friable sandstone occurs; but it is so soft and easily worn away that it has little more effect on the topography than if it were shale.

From the larger proportion of bottom land, and the more gentle slope of the hills, this part of Hancock county is much the best agricultural region. The wide and fertile bottoms of the Ohio river afford rich and valuable farms, while the hill land is all tillable, though not so valuable as the bottoms.

GEOLOGY.

The geological formations represented in Hancock county embrace only Carboniferous and Sub-carboniferous rocks, as follows:

Carboniferous, - -	Coal measures.
Sub-carboniferous, -	Chester Group. St. Louis Group.

By far the greater portion of the county is embraced within the coal measures, which cover all of the western half of the county, and a large part of the eastern. The Sub-carboniferous rocks are found only in the eastern portion of the county; and as they are, both by area and comparative economic value, of less importance than the coal measures, they will be briefly treated.

The St. Louis Group is represented in this county in a very few places, and then only a very small thickness of the upper limestone is exposed. It is found only in the northeastern corner of the county, below the Big Clifty or Tar Spring sandstone. It is of no economic importance, and is hardly worthy of mention in this place, except as the lowest formation of the county.

THE CHESTER GROUP.

The Chester Group has been so often and fully described in the recent reports of the Geological Survey, that it is not necessary to repeat the description here. The character, thickness, etc., of the rocks of this group, and their area in this county, have been stated in the accompanying report on the "geology of the region adjacent to the eastern border of the western coal field," so that a brief statement is all that is necessary here. The reader is referred to the above-mentioned report for more detailed information, should he desire it.

The whole thickness of the Chester Group, from the Big Clifty or Tar Spring sandstone, at the base, to the marly shales and marls at the top, is found in Hancock county, and both of the above-mentioned members are remarkably well developed. Chester rocks are found along the whole eastern border of the county, and extend from three to five miles to the west, inside the county, before they pass entirely beneath the drainage. In almost all this area the ridges, at least, are capped with coal measures; but there are a few isolated corners where the whole area is covered by Chester rocks.

One of these is near the Ohio river, at the northeastern corner of the county; but it is only of very small extent. Here occur the extensive marly shale deposits of the Buffalo Wallow, which have been described in the just mentioned report. These marly shales extend back from the river, along the eastern border of the county, nearly to its southern line; but they decrease in thickness in that direction. They are at their maximum near the river. These shales are also found further to the west near the river, and on Indian creek; but here, too, the thickness is comparatively small.

The Chester limestone is found along the river almost to Hawesville; but the last stream near the river in which it is seen is Indian creek. Back from the river, beyond the head of Indian creek, the Hawesville and Fordsville road may be roughly indicated as a boundary line, to the west of which the Chester rocks will not be found above drainage. This limit is given in more detail in the same report above referred to.

Occasionally, in the eastern portion of the county, a thin coal is found in the Chester rocks. It shows near the river above Indian creek, and is reported at low water in the bank of the Ohio river, above Hawesville. It is of no economic value, as it is never workable; but, in spite of this fact, time and labor are occasionally spent by parties in digging into this coal, in the vain hope that it will prove thicker when followed underground some distance—a hope which, it is needless to say, is never realized.

COAL MEASURES.

The boundary of the coal measures of this county has been already given in the accompanying report, which has been so frequently referred to, and it is shown in the accompanying map by Mr. Page.

Coal-measure rocks are found over nearly the whole of the county, although in the eastern portion they cap only the tops of the hills, the larger part of the area being Chester rocks. From the just indicated line of the disappearance of the Chester rocks, westward to the limits of the county, nothing but coal-measure rocks are found.

We find in Hancock county a maximum thickness of about 475 feet of coal measures, from the base in the eastern part of the county to the highest rocks on the Blackford Creek hills in the western. The greatest thickness measured in any one section is about 200 feet, so that the following general section is obtained by the combination of three typical sections from the eastern, middle, and western portions of the county. Like all general sections, it serves only as an outline or key to the stratification of the county, and is subject to much variation locally. Moreover, in this county the changes in the rocks, which occupy the same geological horizon, are very great, expecially the change from coarse sandstone to shale, and *vice versa;* hence the necessity of the indefinite statement "shale and sandstone," which is used occasionally in the general section. For more detailed illustrations of the character and changes in the rock strata of this county, the reader is referred to the accompanying plates of sections which are drawn from actual measurements at the points named. These sections, with others not published, are the material from which the general section is constructed; but they are more accurate than it is possible to make a general section, which must be averaged from them all:

GENERAL SECTION FOR HANCOCK COUNTY.

24.	Sandstone and shale	20 to 30	feet.		
23.	Coal (?) reported in well	1	"	6	inches.
22.	Coarse, friable sandstone	20 to 30	"		
21.	Shale	15 to 20	"		
20.	Coal, Lewsport coal	3 to 4	"		
19.	Shale and sandstone	40 to 45	"		
18.	Coal	1	"		
17.	Shale and shaly sandstone	15 to 25	"		
16.	Limestone	2 to 12	"		
15.	Coal, Adams', Lawson's, Bruner's, &c.	2 to 4	"		
14.	Shale and shaly sandstone	40 to 50	"		
13.	Coal, Jas. Mason's	2	"		
12.	Shale and sandstone	70 to 88	"		
11.	Coal			4 to 10	"
10.	Coarse sandstone locally changing to shale	50 to 80	"		
9.	Coal, Main Hawesville	2 to 4	"		
8.	Shale and sandstone	40 to 50	"		
7.	Coal ?			4	"
6.	Shale	25 to 30	"		
5.	Coarse sandstone; upper member of Conglomerate?	20 to 30	"		
4.	Shale	20 to 30	"		
3.	Coal			7	"
2.	Shale	4 to 8	"		
1.	Conglomerate sandstone	35 to 60	"		
	Top of Chester limestone.				

The above section holds good for all of the northern and western portions of the county, and as far south, at the centre of the county, as Sulphur Fork of Blackford creek. The southern and southeastern portions, however, present a very different section, and one that is not so well known as yet. Here the section embraces not more than 150 feet of coal measures, which include two or three thin coals. The rocks are not well exposed, but seem to be thin-bedded sandstones and shales. Exposures and developments are so rare that sufficient time has not been devoted to this region to construct a general section which will be of value. The general section given in the accompanying report for the region adjacent to the eastern border of the coal field is more applicable to the southeastern part of Hancock county than the one just given.

The Conglomerate sandstone is not known in this part of the county, or, if represented at all, it is by a coarse, friable sandstone, which is sometimes found below the lowest coal. Going toward the north, the Conglomerate is first found on Caney and Lead creeks, and near the Ohio river it forms a prominent member of the rock series. It will be referred to further along.

In the plates of sections accompanying this report is reproduced the general section by Dr. D. D. Owen for Hancock county, published in volume I, first series Kentucky Geological Reports. The section as originally published embraced also the Sub-carboniferous rocks of Hancock and Breckinridge counties; but that portion of it is not republished, as it is not of especial interest in the present discussion. Dr. Owen, at the time of the publication of his section, had evidently not examined the western part of Hancock county, as he does not include the highest rocks of the county by about 150 feet—his section extending no higher than the rocks immediately below Hawesville, in the hill above the old Hawes shaft.

A comparison of Dr. Owen's section with the sections in the accompanying plates, and the general section just given, will show considerable differences. The upper part of the section corresponds very closely with the sections obtained by the writer, both in thickness and character of rocks, with the single exception that Dr. Owen records a coal eight inches thick, the second coal above the main Hawesville seam, of which the writer has seen no satisfactory evidence.

The lower portion of the section, from the Main Hawesville coal to the base, is, according to Dr. Owen, about fifty feet thicker than any measurements by the writer; and it also shows one more coal than has been seen by him. Dr. Owen, in his report, states that the evidence upon which he placed this coal in his section was obtained from borings made near Cannelton, Indiana, on the opposite side of the river from Hawesville. There was probably some mistake made in the records of the borings, or, if this coal be present on the Indiana side, it is not on this, for the rocks have been seen at too many exposures to leave any doubt in the matter. It is but due to Dr. Owen also to state, that, in publishing this section, he expressly states that it is only preliminary, and subject to correction.

In volume III, first series Kentucky Geological Reports, page 458, Mr. S. S. Lyon publishes the following addition to

Dr. Owen's section for Hancock county, beginning with the upper coal of that section, and including the higher measures of the western part of the county:

Soft yellow sandstone	20 feet.	
Sandy shale	8 "	
Marly shale, with segregations of limestone	3 "	
Black bituminous shale	4 "	
Lewisport coal	4 "	4 inches.
Covered space	36 "	
Sandy shale	6 "	
Sandstone	2 "	
Coal	1 "	
Covered space	14 "	
Limestone	9 "	
Thin sandstone and sandy shale	16 "	
Calcareous chert beds	7 "	
Marly, sandy, indurated mud	1 "	7 "
Very hard, black, pyritiferous limestone		7 "
Coal. Top of Dr. Owen's section	1 "	6 "

The coal at the base of this section is the coal at the top of the hill above the old Hawes shaft, near Hawesville, the coal mined by Mr. Adams on Lead creek, and the coal found to the southwest, in the vicinity of Utility, and on Caney and Blackford creeks.

This section of Mr. Lyon corresponds very closely with those obtained by the writer in his examinations in this county, some of which are given in the accompanying plates; but there is probably a mistake in the number and thickness of the limestones which are shown at the bottom of the above section. There should be but one limestone here, the same which is shown at the top of Dr. Owen's section. This limestone is from two to ten feet thick, and is usually overlaid by shale or shaly sandstone. There is nowhere in this county, within the observation of the writer, any such thickness of cherty rock, or any second limestone overlying this, as represented by Mr. Lyon.

The limestone above referred to is one of the most persistent strata in the whole county. It has been traced all through the western part of the county, from Hawesville, where it disappears, going up the river to Blackford creek. Through all this region it retains its identity remarkably well, and, in consequence, serves as a valuable geological datum.

Mr. Lyon has shown the proper number and position of the coals in the above section.

The general section of Hancock county shows, therefore, a total of nine different coal seams; four of which, namely, the Main Hawesville, the Mason, the Adams or Hawes Hill, and the Lewisport coals, are well-known persistent seams, and are or have been worked. The other seams, especially the two below the Main Hawesville coal, are thin, of no economic importance, and so little has been seen of them that it is impossible to say whether they are persistent or not, and really deserve a place in the general section.

The equivalency of these seams with those in other parts of Western Kentucky is not entirely determined. The section seems not to exactly resemble any other,heretofore published,for the western coal field. In fact, the changes in this county toward the southeast corner are such as to render identification of seams across even that short distance difficult or impossible. The character of the section in the northern and western parts of the county is such that the coal seams can be much more easily traced and identified. There is a large unexamined area around this county to the south and west, between it and other parts of Western Kentucky, where the coal seams have been identified and numbered; but until this area has been carefully surveyed, and the coals traced across it and connected with those of Hancock county, no certain equivalency can be asserted. It is probable that when this is done some of the coals will be found occupying the positions of certain of the more persistent and trustworthy seams of the western coal field, and that others will be found to be local. In the meantime, the equivalencies which seem the most probable may be stated, but it will be subject to revision.

In the report of the Geological Survey of Indiana for 1872, page 98, Mr. E. T. Cox, the State Geologist of Indiana, while discussing the geology of Perry county, Indiana, which lies across the Ohio river from Hancock county, Kentucky, gives a section at the Hawes mine, including the hill above. This section extends from the Main Hawesville to the Adams coal, the upper coal of Dr. Owen's general section for this county. Mr. Cox's section is as follows:

Slope.		
Sandstone "Anvil Rock?"		
Sandy shale.		
Limestone	6 feet.	
Coal K, with 12 inches of clay parting	2 "	6 inches.
Sandstone and shale	60 "	
Coal I.		
Sandstone and shale	80 "	
Coal H	1 "	6 "
Sandstone	30 "	
Coal G	1 "	
Hard, bluish shale	25 "	
Black bituminous shale	15 "	
Coal F, "Hawes Coal"	4 "	

The above section is copied exactly as published by Mr. Cox. He has used his Indiana nomenclature for the different seams, for the purpose of comparison with his sections for Perry county, Indiana. The measurements of this section agree fairly well with those obtained at the same place by the writer, except that the total distance from the main Hawesville coal to the coal at the top of the section is some ten feet greater. Mr. Cox, however, records a coal G, which the writer of this has no certain evidence of. It is probable that Mr. Cox has placed it in the section, from the report of its having been found in the Hawes shaft. It is stated that there was such a coal passed through in sinking the shaft, but it is also denied on equally good authority; and as there is little evidence of it at any other point, it has not been deemed best by the writer to give it a place in the section.

In volume III, 1st series Kentucky Geological Reports, page 563, Mr. Cox, who was then an Assistant of the Kentucky Geological Survey, identifies the coal at the top of this section as No. 11 of the Kentucky general section. This identification is apparently from palæontological evidence only. In the Report of the Indiana Geological Survey, above referred to, he repeats his belief in this identification, and refers to the surprise of himself and Prof. Lesquereux "on finding at Hawes' mine, near Hawesville, the whole of the coal-measure strata, from the 'Anvil Rock' sandstone to the Conglomerate sandstone."

That Prof. Lesquereux did not agree with Mr. Cox in this identification as No. 11, is evident from the fact, that, in his report, volume III, 1st series Kentucky Geological Reports, page 535, he refers to this coal as No. 3. That Mr. Cox is mistaken is readily ascertained by a short examination of the stratigraphy of the western part of Hancock county. The character of the rocks here is shown by the general section and the sections of the accompanying plates. It is shown in these sections that there is a thickness of about 125 feet of strata, including two, and perhaps three seams of coal, one of which is of workable thickness, and is one of the most trustworthy coals in the county, above the coal which Mr. Cox identified as No. 11, and the sandstone which he calls the "Anvil Rock." Of this fact there is the most complete stratigraphical evidence, for the rocks which identify and connect the sections can be traced without difficulty from the Hawes hill to the western part of the county, where they pass under the sections which show the Lewisport coal. This coal is the second seam above the coal at the top of Mr. Cox's section. The distance between is from 60 to 70 feet.

Prof. Lesquereux, in volume III, first series Kentucky Geological Reports, page 544, identifies the Lewisport coal as No. 9. This identification, like that of Mr. Cox, seems to be based entirely upon palæontological evidence. Prof. Lesquereux has, therefore, identified one coal as No. 9, while another, which is known, from the best stratigraphical evidence, to be only 70 feet below, he has called No. 3. Mr. Cox has called the same coal No. 11.

According to Dr. Owen's general section for the western coal field, the normal distance from coal No. 9 to coal No. 3 is about 500 feet. The distances, according to Dr. Owen's section, are undoubtedly somewhat too great, as shown by Mr. Norwood's more recent sections in the central and southern part of the field; but no such great decrease in the thickness is known as would be indicated by the above identification.

These discrepancies and mistakes afford a striking instance of the incompetency of palæontological evidence alone, even when in the ablest hands, for the identification of coal seams over any great distances. Palæontological evidence is undoubtedly of great value, when used in connection with and as corroborative of stratigraphical evidence, but alone, it is insufficient to give a trustworthy basis for conclusions.

The identification by Prof. Lesquereux of the Lewisport coal as No. 9 is possibly correct, although it is by no means certainly determined, as it yet lacks the stratigraphical evidence necessary to settle its equivalency beyond a doubt; but the position of the coal, its persistence and uniformity of thickness, as well as the evidence from its palæontology, which convinced Prof. Lesquereux, all tend to prove that it is the No. 9 coal, or coal D, using Mr. Norwood's temporary nomenclature for the coal seams of Western Kentucky. If this be the case, it shows a thinning of the section of the western coal field, much beyond even that indicated by Mr. Norwood's sections, in the region adjacent to the Louisville, Paducah and Southwestern Railroad.

The coals of the lower part of the section for Hancock county have not yet, and cannot, in the present state of our knowledge, be positively identified and numbered with the seams of the general section for the western coal field. It has been deemed best, therefore, to give them only the local names, which will serve to identify them throughout the county, and to leave the final numbering until the connection has been traced across the interval which now separates them from parts of the coal field where the identity and equivalency of the coals have been well established.

The number of coals in the general section for the western coal field, and the final nomenclature to be adopted, have not as yet been determined, and it is therefore best, before forcing a classification in any one section, to wait until the field has been more widely studied, and it can be found which coals are persistent and thick over the whole field, and which are only local.

DESCRIPTIVE GEOLOGY.

The geology of the southeastern part of this county has been outlined in the discussion of the topography; and it has been stated that it differs in the character of its prevailing rocks from that part nearer the river. The Conglomerate sandstone is here missing, and there is a greater prevalence of shales and thin sandstones. With one very valuable exception, the coals seem to be thin. It is but justice to say, however, that exposures are rare, and that thorough prospecting does not seem to have been done over much of the region; but where seen, the coals were mostly thin, and they are reported thin at other places where not seen.

The exception above referred to is the celebrated Breckinridge cannel coal, the mines of which lie in the edge of Hancock county, on one of the head branches of Tar Fork. This coal has been made the subject of a special report by Mr. Norwood, in which its value is discussed at length. To this report the reader is referred for detailed information. It is necessary here to repeat only a few facts in regard to its position, etc., in its relation to the general section of the county.

It is a cannel coal of excellent quality, from 24 to 33 inches thick, occurring from 25 to 30 feet above the Chester limestone, with a coarse, micaceous, soft sandstone between. The hills in the vicinity of the mines rise about 100 feet above the coal. There are but few exposures of the rocks above the coal, and a full section has not been obtained. The following section, obtained at a shaft recently sunk in this vicinity, shows a portion of the rocks in the ridge above the coal in more detail than anything heretofore published. The records of the shaft were obtained from Mr. M. R. Taylor, of Cloverport, by whom it was sunk. At the time of visit, the shaft was full of water. The bottom of this shaft is probably 10 or 15 feet above the coal. The exact level was not determined. The location of the shaft is not more than one half mile distant from the entries in the valley:

SECTION.

Soil	9 feet.	
Grey shale	10 "	
Shaly coal		2 inches.
Light shale	10 "	
Band of iron ore		1½ "
Dark bituminous shale	8 "	
Coal		3 "
Very black shale	18 "	
Sandy shale	3 "	
Total	58 "	6½ "

This coal, like all cannel coals, seems to lie in a basin of limited extent, and at a distance of a few miles on all sides it is no longer found. The present mines are in the dividing ridge between a branch of Tar Fork and Panther creek. The drifts are all on the Tar Fork side. On the Panther creek side of the ridge it is reported that the coal has been found at a number of localities; but it was long since the explorations were made, and the openings have all fallen in, so that nothing can now be seen of the coal at any of them.

To the west of this the coal has not been seen by the writer, and very little has been heard in regard to it. At the time of the development of the property extensive explorations were made by the company operating the mines; but nothing has been learned as to the results which they attained. It is probable, however, that the results were negative, or the facts would be known. To the southwest, on Adams' Fork, in Ohio county, is an exposure of cannel coal or cannel shale, which probably occupies the position of this coal. It has been described in the accompanying report on the "Geology of the Region Adjacent to the Eastern Border of the Western Coal Field."

The equivalency of the Breckinridge cannel coal has long been a matter of discussion. It is undoubtedly the lowest workable coal of the section, and, as such, the equivalent of coal No. 1B of the old reports, or coal L, using Mr. Norwood's temporary nomenclature; but, in the opinion of the writer, it occupies an independent basin, and cannot be traced to an absolute identity with any other seam, although it may occupy nearly the same position.

On Panther creek few coals have been seen; but those reported are mostly thin, and have never been worked to any extent, though often opened for exploration.

The Chester limestone disappears below the drainage on Panther creek, near Mr. S. G. Lane's. From here to the western border of the county, in the vicinity of Pellville, the dip of the rocks is slight, not over 20 to 30 feet to the mile. The total thickness of rock above the base of the coal measures is not more than from 200 to 250 feet. The principal features of the topography have been before described. Toward the west the hills decrease in height, and slope more gently, while the prevailing rock is shale. There is a considerable area in the southwestern portion of this county and the adjoining region, in Ohio county, where these characteristics prevail, and where there is an unusual thinning of the coals. The coal best known seems to be the equivalent of the Fordsville coal, described in the accompanying report. It is, however, usually thin, rarely measuring as much as 24 inches in thickness, and more commonly 18. The only workable coal known in this region is at Mr. R. S. Lanum's, in Ohio county, about one and a half miles southwest of Roseville. The coal here at the mouth of the entry, and for some distance back, is only about 20 inches thick; but it gradually increases in thickness, until at end of the drift, about 100 yards in, it measures 40 inches, including 3 inches of slaty coal at the bottom. The equivalency of this coal was not satisfactorily determined, but it is probably coal H. It lies here very near the drainage level, and probably passes below to the west. The following is an analysis by Dr. Peter and Mr. Talbutt of a sample of coal from this bank:

Moisture	6.00	
Volatile combustible matter	37.80	
Fixed carbon	48.70	Coke 56.20
Ash	7.50	
Total	100.00	
Sulphur	3.180	
Specific gravity	1.292	

Going toward the Ohio river, coarse, hard sandstones occur in increasing frequency and thickness, and, in consequence, outcrops are more numerous, and it becomes easier to trace the strata across the country, and to determine the geological horizon at any point.

The most prominent of these sandstones is the Conglomerate. This here, as almost everywhere else in Western Kentucky, is very irregular in its occurrence and thickness. It is first seen going toward the north, near the heads of Caney and Lead creeks. To the west it disappears below the drainage on Caney creek, a short distance above the crossing of the Hawesville and Pellville road; on Lead creek at the same road crossing, and on the Ohio river at the branch which runs through the upper part of the town of Hawesville. Its further continuation to the westward is here cut off by a fault, and a fold or bend in the strata, which bring the rocks on one side of the ravine about 90 feet lower than they are on the other. The absolute fault or slide in the rocks is probably not more than 20 or 25 feet; but there is a very steep dip close to the line of this fault, which brings the rocks down the remainder of this distance before it is modified. This is proved by the fact that the coal has been worked up to the fault line at several places, so that the dip can be very closely followed.

The Conglomerate here consists of two members, only one of which, however, the lower, is commonly known as the Conglomerate. This is here from 35 to 45 feet thick. Above it, separated by from 15 to 30 feet of shale, is another coarse sandstone, from 20 to 35 feet thick, which is also, at places, conglomeratic, being largely composed of small and rather angular quartz pebbles. These pebbles are more abundant further up the river, toward Indian creek, than near Hawesville. There is a thin coal in the shale between these two sandstones, from five to eight feet above the top of the lower. It has occasionally been dug into, in the hope of finding it thick enough for profitable working; but the greatest thickness reported is seven inches.

The presence of two Conglomerates, with a coal between, is not an unusual occurrence in the western coal field. They occur in Edmonson county, and are shown in the sections of part II, volume II, second series Kentucky Geological Reports. They are also noted on the western border of the field, in Livingston county, by Mr. Norwood, in his report, part VII, volume I, second series.

Both of these sandstones, near Hawesville, furnish excellent building stone. They have both been largely quarried, but the upper one most extensively. From the quarries here a large part of the rock for the locks on Green river, for the Government building at Memphis, and other extensive public works, was obtained. A sample of the stone from this quarry received an award at the Centennial Exhibition in Philadelphia in 1876.

About three miles from Hawesville the two sandstones can no longer be distinguished as independent beds, but instead, we have a massive Conglomerate, very conspicuous and frequent in outcrop, about 75 feet in thickness, which seems to represent them both. The change by which this is effected is obscure and has not been traced in as great detail as could be desired; but it is the only hypothesis which satisfactorily explains certain apparent great changes in the position of the coals above.

About 60 feet above the lower Conglomerate, and 20 feet above the upper or quarry sandstone, in the river hills above Hawesville, a thin coal is reported to have been found at several places. It is stated as only four inches thick, and therefore of no economic importance. It has not been seen by the writer except in very indistinct outcrop; but the authority upon which it is reported is so good, that there is little hesitation in placing it in the section. It is shown in plate I of the accompanying sections. This coal, and the other thin coal lying close to the top of the lower Conglomerate, occur on the opposite side of the river in Indiana, and are shown in the sections of Mr. Cox's report on the geology of Perry county. These sections of Mr. Cox uniformly show greater distances between coals than have been obtained by the most careful measurements on the Kentucky side of the river; but otherwise they generally bear a close resemblance in the character and order of the different strata.

There is but a very small area in Hancock county where these two coals are known, as they pass below the drainage to the west about the same time the Conglomerate does, and to the east the lower one disappears with the change in the Conglomerate just referred to, while the upper ot the two, even if it extend as far as the underlying Conglomerate, has but a very limited range. It is only known in the immediate vicinity of Hawesville.

THE MAIN HAWESVILLE COAL.

At 110 feet above the lower or main Conglomerate, occurs the coal which is best known, has been most worked, and is of most value in Hancock county. It is generally known as the Main Hawesville coal, a name which was used in the 1st series Kentucky Geological Reports, and which will be retained here. It is the same coal as the Cannelton coal of Perry county, Indiana.

The coal varies greatly in thickness, occurring over considerable areas, ridges, as it were, in the coal seam, where it is hardly more than a streak, and then covering other areas, where it is from 3 to 4 feet thick. In the mines where it is worked, it varies from 2 to 4 feet, with an average of perhaps a little more than 3. Below the coal, between it and the fire-clay, is commonly found a very hard bituminous slate, which ranges from 4 inches upward, becoming thicker as the coal thins, until it often forms the main body of the seam. The upper part of the seam is usually of a semi-cannel coal, but this is only a few inches. The main portion is a rather dry bituminous coal, of very good quality.

The distance between this coal and the main Conglomerate is not as great as stated in the reports of Dr. Owen, nor as reported in Perry county, Indiana, by Mr. Cox, who places the distance at 148 feet, in Cannelton. It has been measured carefully with aneroid barometer, hand level, and finally with spirit level and rod; and in no case has it, near Hawesville, been found more than 115 feet. This coal,above Hawesville, at the old mines, is about 150 feet above high water in the Ohio river. From here it dips to the west, until, just above Hawesville, it is about 100 feet above. The fault and bend in the rocks before referred to, at the upper edge of Hawesville, bring the coal down to 10 or 15 feet above, and at the lower edge of town it is near the level of high water or a little below. Here another fold occurs, which increases the dip, until, less than a mile below, the coal was found in the old Hawes shaft, before referred to, 70 feet below high water in the Ohio. These disturbances in the rocks do not seem to extend to the south beyond Lead creek. The coal has been worked through the hill from Hawesville to Lead creek, west of the fault line. There is probably a cross-fault running down the valley of Lead creek; for, on the north of the creek, where this coal has been worked, it is about 25 feet above the creek, while on the hill south, in the old Pellville road, the same coal is 135 feet above. This fault does not seem to extend more than one half mile above the Pellville road crossing, as above this the coal occupies very nearly the same level on both sides of the creek.

At the Hancock mines, in the ridge between the waters of Indian and Lead creeks, a little more than three miles southeast of Hawesville, this coal is only from 50 to 55 feet above the top of the Conglomerate, which is here at its maximum thickness. The different members cannot be distinguished here, and it is probable that the upper and the lower are united. The space between the top of the Conglomerate and the main coal is covered, so that nothing could be learned as to the presence of the thin coal next below it. The decrease in the distance between the main coal and the Conglomerate, at this place, is marked. It is even less than the usual distance from the top of the second Conglomerate or quarry sandstone to the coal, and about half the distance from the lower Conglomerate. This decrease occurs in less than two miles distance from some of the old drifts above Hawesville, where the coal is at its normal height above the Conglomerate.

If this decrease in the distance between the coal and Conglomerate toward the southeast be continued beyond the head of Lead creek, it strengthens the hypothesis of the equivalency of the Main Hawesville and the Breckinridge cannel coals, both of which were classed as No. 1B by Prof. Lesquereux, in volume III, first series Kentucky Geological Reports. The stratigraphical evidence has, heretofore, seemed strongly against any such equivalency; but the disappearance of one of the thin coals below the Main Hawesville seam, and the probable disappearance of the other, the persistence of the main seam, and the lessening of the distance between it and the Conglomerate, all tend to encourage the hypothesis that further to the southeast this coal may be the lowest coal of the basin, as it is here undoubtedly the lowest workable seam. This, however, has not as yet been proved, and cannot be until the coal has been carefully traced across the intervening space between the Hancock and the Breckinridge mines—a matter of much difficulty as yet, as hardly any openings have been made, and natural outcrops are extremely rare.

The Hancock mines are the most extensively worked, at present, of any in this county. They are owned by the American Cannel Coal Company, of Cannelton, Indiana. The coal is shipped to the river by a railroad about two and one half miles in length, the grade of which is sufficient to allow the cars to run of their own weight to the river, from which they are hauled back by mule power.

The main coal has been mined in the vicinity of Hawesville for more than thirty years past. The old Reverdy and Trabue mines were among the first and largest on the lower Ohio. At present, however, nearly all of the available coal in the river hills near Hawesville, between the river and Lead creek, has been exhausted, and no mining is now carried on here, save in a desultory manner for local supply, in corners and patches, which were left unexhausted when the large mines were abandoned. All of these mines were worked by drifts. At the old Hawes mine, below Hawesville, the coal was reached by a shaft variously reported from 60 to 80 feet deep. The mine, however, running under the Ohio river bottoms, was a very wet one, and finally had to be abandoned on account of the great influx of water, although the coal available from the shaft was not exhausted.

In the vicinity of Hawesville, the coal is reported to have been very irregular in thickness, frequently occurring over considerable areas entirely too thin to be worked. These areas probably occur at the summits or ridges of waves in the coal seam. In the country back of Hawesville there is yet a large area of this coal of workable thickness, good quality, and wholly undeveloped. In fact, it has hardly been fairly prospected; but enough is known to justify the assertion that there is here a vast amount of cheaply available coal. It is to this region that the people of Hawesville and the central part of Hancock county must look for a renewal of their former mining prosperity. The supply of coal is ample, both in thickness and area, for many years of continued and extensive mining operations.

In the ridge between Lead and Caney creeks, south of Hawesville, this coal has been opened at a number of places, but at only one of these, near the Hartford road, was it seen. This is called the Breckinridge bank. The coal is here 44 inches thick, but this includes 6 inches of bituminous slate at the bottom; so that the clear coal measures only 38 inches. Near the old Pellville road, the coal has been opened in two places; but they have now fallen in, so that nothing could be seen of the thickness. It is reported to be 3 feet thick; but this is denied by others, and the statement is made that it was found too thin to work. The fact that the drifts were abandoned without mining any amount of coal tends to confirm this statement. The coal dips rapidly to the west from the old Pellville road, where, as already stated, it is 135 feet above Lead creek, until it is only found above the drainage level a short distance west of the new Pellville road. This rapid dip is probably produced by the continuation to the southward of one of the folds which were noted at Hawesville. The same coal is now being worked in a small way on the waters of Lead creek, between the creek and the river, some distance above the Hartford road. Here, at the time of visit, the coal measured 34 inches, and the under slate 14. Little is known of the coal on the south branches of Lead creek, above here, until at the head of the creek, in the ridge between it, Caney creek, and Sulphur fork of Blackford, where a bank was formerly opened, and the coal hauled to Cloverport. It is reported to be nearly 4 feet thick at this place, but access could not be had to it to measure it, as the drift had partially fallen in. From what could be seen, however, it seems likely that the thickness is not very greatly overestimated.

On Caney creek, and in the ridge between that stream and Blackford creek, this coal is well developed, and has been opened at a number of localities sufficiently well to show its character and thickness. The nearest opening to the one just described is at Mr. J. Richey's. Here the coal is so near the level of the creek that the drifts had filled with water at time of visit, and the coal could not be measured; but it is reported to be three feet thick.

About one mile west, at the Jesse Rice bank, the coal has been opened, and shows a thickness of forty-seven inches, including three inches of bottom slate.

Still further down the creek Mr. Jacob Royall has a drift in this coal, where it is forty-two inches thick. This drift is near the Pellville road.

There is a marked undulation in the rocks along Caney creek between the crossings of the Fordsville and the Pellville roads. At Mr. Richey's, in the Fordsville road, the coal is near the level of the creek. At the Jesse Rice bank it is 30 to 40 feet above. Between the Hartford and the Pellville roads, at Mr. T. Burkis', the Conglomerate rises to 20 or 30 feet above the creek level, descending rapidly again to the west, and passing below the creek before the Pellville road is reached. The coal at the Royall bank is about 60 feet above Caney creek.

This reversal of dip may be due to some as yet undiscovered fault or faults, the continuation to the southward of the more marked disturbances at the river; but the region has not yet been studied in sufficient detail to justify the positive assertion that this is the case.

On the Blackford creek side of the ridge the coal has only been seen well exposed at one locality—Mr. John C. Schafer's bank. It is on a small branch running into Blackford creek below the Pellville road crossing, and about one mile distant from the creek. It is about 50 feet above the creek. The coal here is of excellent quality, being freer from sulphur than at any other place from which a sample has been analyzed. It is 43 inches thick, including about one and one half inches of shale parting.

The same coal was formerly opened on the old Taylor place, near the Blackford Meeting-house, on the Pellville road. It is reported to be about the same thickness as at the Schafer bank. South of Blackford creek the coal was formerly opened at Mr. Glover's, on the Pellville road; but it cannot be seen now. It is reported 30 inches thick. At Mr. Baker's, where it is next seen beyond Mr. Glover's, it is only 18 inches thick. Beyond Mr. Baker's to the south, the coal has not been positively identified. To the westward it passes below the drainage between the Pellville and Knottsville roads, and a higher coal becomes the best known seam.

QUALITY OF THE MAIN HAWESVILLE COAL.

The following analyses, by Dr. Peter and Mr. Talbutt, Chemists of the Survey, from samples selected by the writer, serve to show the chemical composition of the coal from this seam. The samples were intended to be as nearly representative of the whole thickness of the coal as possible:

	1	2	3	4	5
Moisture	5.12	3.30	5.20	5.10	7.46
Volatile combustible matter	36.28	39.00	38.70	41.20	33.14
Fixed carbon	47.60	50.50	48.50	46.60	55.20
Ash	11.00	7.20	7.60	7.10	4.20
Total	100.00	100.00	100.00	100.00	100.00
Coke	58.60	57.70	56.10	53.70	59.40
Sulphur	4.038	3.373	2.266	3.331	1.368
Specific gravity	1.357	1.268	1.336	1.292	1.308

No. 1 is from the Hancock mines.

No. 2 is from the Davidson bank, near Lead creek, above Hawesville.

No. 3 is from the Bergenroth bank, Lead creek.

No. 4 is from the Bridenbach bank, south of Lead creek.

No. 5 is from the Schafer bank, near Blackford creek.

It is probable that, in selecting the sample No. 1 from the Hancock mine, too much coal was taken from the lower part of the seam, where it is becoming slaty; hence the per centage of ash is probably shown larger than the proper average of the whole seam.

The character of the rocks above the Hawesville coal is subject to great variation. Shales and coarse sandstones alternately overlie the coal, and change from one to the other frequently. Near the Hancock mines, it is reported that in one of the exploration shafts sunk when the property was in process of development, a thickness of 50 feet of shale was passed through before reaching the coal. Above this shale, however, a coarse sandstone from 20 to 25 feet thick occurs.

Nearer Hawesville, at the old Reverdy mines, a coarse sandstone occurs from 15 to 20 feet above the coal; the space between is probably filled with shale, but it is covered so that it was not seen.

At the upper part of the town of Hawesville there is a thickness of about 50 feet of shale above the main coal, between it and the massive sandstone which caps the hill here.

Near the top of this shale a thin coal is reported, but has only been seen here by the writer as a "stain."

It is probable that this is the first coal given in the general section above the main coal. Below the fault at this place the sandstone comes rapidly down to the coal, until at the old drifts, in the lower part of town, it is almost immediately above, separated by only from 5 to 7 feet of shale. A second sandstone appears here about 30 feet above the first, and the coal next above the Main Hawesville lies between them, about 60 feet above it. This coal was once opened here, it is reported, and found to be about one foot thick. The character of the rocks here is shown by a section in plate I. South of Lead creek, as far as Blackford creek, the coal is closely overlaid by a coarse sandstone about 30 feet thick. Beyond Blackford creek this sandstone disappears.

The fold in the rocks, at the lower edge of the town of Hawesville, brings the coal next above the main seam down to the level of a small branch called Persimmon run, about one half mile below town. The coal is here washed bare in the bed of the branch. It is only 4 inches thick, but is overlaid by from 2 to 3 feet of very bituminous shale, which gradually changes at the top to clay shale. The section here is as follows:

Hard sandstone	6 feet	
Covered space	10 "	
Clay shale	10 "	
Bituminous shale	2 "	
Coal		4 inches.

This is probably the same coal which was once opened a little above high water mark, near the mouth of the old Hawes shaft. Its position is shown in the section at this place, plate II. The coal, which is reported to have been formerly exposed in the bed of Lead creek, at the crossing of the Owensboro and Hawesville road, is also probably referable to this seam, but, relatively, it is 20 or 30 feet higher than the usual position of the seam. Beyond this, to the west or south, this coal is not again seen above the drainage in this county, and nothing is known of it.

About 90 feet above this coal, and from 40 to 50 feet below the limestone near the top of the Hawes hill, is another seam of coal, which has about the same easterly limit as the one just described, but extends considerably further to the west, above drainage. It has been seen as a "stain" at a number of places, sections at some of which are shown in the accompanying plates; but it has only been opened so that it could be well examined at one place, Mr. James Mason's bank, about six miles below Hawesville. The coal is here 24 inches thick, in addition to 6 inches of bituminous slate at the bottom. The bank is worked considerably for the supply of the neighborhood. The position of the coal is shown by a section of plate II.

This coal has not been seen west of this in Hancock county, as it probably soon passes below the drainage, but not far below; for it is seen just above low water, in the bank of Blackford creek, a short distance from its mouth, at a locality known as the Shaw Hills, in Daviess county. A section here is shown in plate III. Blackford creek is here the line between Daviess and Hancock counties. The coal was imperfectly seen here, so that no measurement of thickness could be obtained. It is reported to be nearly 3 feet thick; but the accuracy of this report is not vouched for. There is a very slight reversal of dip, which brings the coal to the drainage level here.

The western limit of this coal for Hancock county, where it lies above drainage, is a line running nearly south from Mr. Mason's, striking Blackford creek below the mouth of Caney.

The following analysis, by Dr. Peter and Mr. Talbutt, from a sample selected by the writer, shows the quality of the coal at Mr. Mason's bank. The sample was not quite satisfactory, as the coal was near the outcrop and muddy at the seams; hence, it probably contains too much ash:

Moisture	4.80	
Volatile combustible matter	38.90	
Fixed carbon	50.06	Coke 56.30.
Ash	6.24	
Total	100.00	
Sulphur	2.316	
Specific gravity	1.289	

The coal at this place has been incorrectly referred by Mr. Lyon in volume III, first series Kentucky Geological Reports, page 463, to the seam beneath the limestone at the Hawes mine hill. This seam is shown by its "stain," immediately under the limestone, in the ravine, about 50 feet above the Mason coal. Mr. Lyon is also probably mistaken in referring the sandstone at the bluffs above Mr. Mason's house to the sandstone immediately over the Main Hawesville coal, and stating that the coal is here not more than 30 feet below the surface. The position of the sandstone is shown in a section of plate II. The base of it is less than one hundred feet below the Hawes Hill limestone, and hence more than that distance above the Main Hawesville coal.

Next above the just described coal lies the coal which has been already so many times referred to as occurring immediately under the Hawes Hill limestone. The eastern limit of this coal is a line running nearly south 20° west from the Ohio river, at the lower edge of the town of Hawesville, at the fold heretofore described, to the southern boundary of the county. This coal does not at any point extend far east of the Hawesville and Knottsville road; and, in an approximate way, it might be taken as the eastern limit of the coal.

To the west this coal extends to the county line and beyond. In the lower valley of Yellow creek it lies very near the drainage level, and at some places a little below it, but at no point more than a few feet. The same is true of the Blackford creek valley for some distance below the crossing of the Hawesville and Owensboro road; but lower down, at the Shaw Hills, already referred to, this coal is above high water mark. (See plate III.)

At the Ohio river, where first seen, the coal is too thin to be of any great value. Near the old opening, at the Hawes hill,it is only 25 inches thick. At the Adams bank, two miles below, it is about the same thickness. Going south, this coal thickens, and becomes the most valuable and accessible coal of the central part of the county. Between Lead and Caney creeks, at the Wilson and Lawson banks, it is 30 and 32 inches thick, while further south, between Caney and Blackford creeks, at the H. Bruner bank, it is a fine seam of 44 inches thickness, including, however, a parting of 2 inches. South of Blackford creek, just across the line in Daviess county, near the Friendly Grove school-house, at the Duncan bank, this coal is 48 inches thick, without parting. Through all this region this coal lies well above the drainage, and can be readily mined. In the western part of the county it has been rarely opened; and, although the limestone which overlies it is often seen, the coal is rare in outcrop. A drift was run in this coal at the Shaw Hills, on Blackford creek, but had fallen in at the time of visit, so that the coal could not be measured. It is reported between 2 and 3 feet in thickness. The section here is shown in plate III.

The following analyses, by Dr. Peter and Mr. Talbutt, from samples taken by the writer, show the character of this coal:

	I.		II.	
Moisture	5.40		6.20	
Volatile combustible matter	34.80		41.90	
Fixed carbon	49.30	Coke 59.80.	47.40	Coke 51.90.
Ash	10.50		4.50	
Total	100.00		100.00	
Sulphur	2.398		3.743	
Specific gravity	1.353		1.285	

No. 1 is from Milton Lawson's bank, near Hawesville and Knottsville road.

No. 2 is from the Duncan bank, Friendly Grove schoolhouse, Daviess county.

The limestone above this last coal has been referred to several times. It is quite persistent in occurrence, although varying locally in thickness. At places near the river, near its eastern limit, it is 8 or 10 feet in thickness; but toward the west it decreases to 2 feet. Where it is thick, the bottom is usually cherty, but where thin, it is a moderately pure, dark-colored limestone.

About 20 to 30 feet above the last described coal lies another, which is as yet known only at a few places in the western portion of the county; but it has been seen frequently enough, and its place so well determined, as to justify giving it a place in the general section. It is the coal at the base of the hill below the old Lewisport mines, the coal reported to have been found in the well at Mr. J. Colbert's, the coal at the old lick above Mr. D. Driscoll's, and the coal showing as a "stain" in the roadside at the crossing of Blackford creek by the Owensboro and Hawesville road. It is also probably the coal reported by Gen. Adair, of Hawesville, as occurring above the limestone in the Hawes hill.

At none of these places is it more than 18 inches thick; and hence it is not probable that it will be found thick enough to be of economic value. It is not worked in this county.

We now come to the coal known as the Lewisport seam, which is the most valuable coal of the western part of Hancock county, and perhaps the most trustworthy coal as regards thickness of any in the county. It is called the Lewisport seam, from the fact that it was formerly mined back of, and shipped from, the place of that name. Its position is 40 to 50 feet above the last described coal, or about 275 feet above the Main Hawesville seam.

The field of the coal lies in the ridge between the waters of Blackford and Yellow creeks, and out on the spurs toward

Blackford creek. Unfortunately, this area is not large in Hancock county, as it embraces but a few square miles.

To the east, it does not extend beyond the head of the South Fork of Yellow creek, as the rise of the rocks in this direction brings the coal to the tops of the hills. To the west, it extends to Blackford creek, the boundary of the county. The dip of the coal is, to the west, from 25 to 50 feet to the mile, this latter, however, being probably local, as the rate was only observed at one place. Some levels have been run at the different exposures of this coal, partly by Mr. Page and partly by the writer, for the purpose of determining the dip. At the Robert Estes bank, which is the most eastern opening at present, the coal is 101 feet above high water in the Ohio river. From here south, the coal lies nearly horizontal or rises a little. At the Colbert bank the coal is at the same level; at the Billings bank it is 6 feet higher, while at Wm. Richardson's, on the Owensboro and Hawesville road, it is 114 feet above high water. At G. W. Lott's, west of this place, on the same road, the coal is only 56 feet above high water, and at the old Lewisport mines it is 59 feet above.

This coal has been mined at a number of places, both on the Yellow and Blackford creek slopes, and is usually from four to four and one half feet thick, without parting of any appreciable thickness. Several of these openings have been mentioned above. But few of them are now worked, and these only for local supply, as no coal is now shipped by the river. The old Lewisport mines, whence the coal was shipped, were opened in a very narrow ridge, where the coal was soon exhausted. There is an abundant supply in the main ridges a little further back from the river, where the coal is regular in thickness, and situated very favorably for cheap mining.

The following analysis, by Dr. Peter and Mr. Talbutt, of a sample of coal collected by the writer from the Estes bank, will serve to show the quality of the coal of this seam:

Moisture	3.50	
Volatile combustible matter	43.40	
Fixed carbon	45.56	Coke 53.10.
Ash	7.54	
Total	100.00	
Sulphur	4.155	
Specific gravity	1.323	

The coal at No. 23 of the general section, about 50 feet above the Lewisport seam, has been given a place in the section provisionally and with extreme hesitation. It is known at only one place—Wm. Richardson's, on the Owensboro and Hawesville road—where it is reported to have been cut through in sinking a well, and that it was 18 inches thick.

There are but few places in this county where the hills are sufficiently high to contain this coal; so that, even if it were thick enough to be workable, it could be of no economic importance.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

A GENERAL ACCOUNT

OF THE

GEOLOGY OF A PART OF OHIO COUNTY,

BY CHARLES J. NORWOOD.

STEREOTYPED FOR THE SURVEY BY MAJOR, JOHNSTON & BARRETT, YEOMAN PRESS, FRANKFORT, KY.

PRELIMINARY LETTER.

Professor N. S. SHALER, *Director Kentucky Geological Survey:*

DEAR SIR: I herewith present the results (that are ready for publication) of my work in Ohio county. It is proper to state, that a number of matters have been left undiscussed, although notes were taken concerning them, as it seemed best that they should be considered in a report dealing with the county considered as a county alone. In this report the county is especially considered with respect to its value in aiding to make clear the history of the western coal field.

The acknowledgments of the Survey are due the citizens of the county generally for their coöperation in furthering the work in their respective regions, but especially are they due Mr. Harrison D. Taylor, Judge Baird, Dr. J. E. Pendleton, Hon. E. Dudley Walker, Mr. J. P. Barrett, and Mr. Carson, of Hartford; Mr. R. B. Thomson, of Elm Lick, and Mr. S. Woodward. Dr. Pendleton, Mr. Carson, and Mr. Woodward presented specimens of archæological value to the Survey; Mr. Taylor and Judge Baird furnished maps, and Mr. Thomson rendered very material assistance to me in a number of ways.

Respectfully,
C. J. NORWOOD.

A GENERAL ACCOUNT OF THE GEOLOGY OF A PART OF OHIO COUNTY.

PREFACE.

The conditions of the beds in Ohio county depend essentially on two nearly parallel disturbances, one of which is an uplift, apparently a synclinal, and traverses the county in an irregular eastwardly and westwardly direction; the other, a disturbance lying within the counties to the south of the Ohio line, near the southern border of the coal field, and which seems to have been, in a large degree, instrumental in shaping the form of the southern limit of the field.

The counties nearest to Ohio county, within which this southwardly disturbance lies, are Butler and Muhlenburg. Accordingly, the southern part of Ohio county, and the northern parts of Butler and Muhlenburg counties, are found to lie within a common geological basin, which is a synclinal one.

North of the Ohio county disturbance the beds seem to have one general sweep—a downward one—towards the north, nearly, if not quite, to the Ohio river. The amount of the depression of the beds, however, varies in that direction; apparently being inconsiderable in the direction of Hawesville, Hancock county, but sufficient in the direction of Owensboro', Daviess county, to bring the upper coals within the hills facing the river, near that city.*

We find, therefore, in Ohio county two distinct geological areas: one occupying the southern half of the county, and forming, with parts of Butler and Muhlenburg counties, a synclinal basin, which reaches from Rough creek to the southern margin of the coal field; the other, an area with a single slope, and that towards the north. There certainly are local modifications of these conditions; but such seems to be a correct view of the *general* arrangement of the geological features of the regions.

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*It is possible that the very low rocks seen at Hawesville (beds at the base of the coal measures are visible there) may have been brought to light by another disturbance—causing a northwardly rise of the beds. Of this, however, I have no accurate knowledge, and refer to the forthcoming report of Mr. P. N. Moore, on the geology of that region, for the solution of this question.

The two regions seem to differ in some special particulars besides the relative positions, towards the surface, of the beds beneath it.

There seem to be indications of a wedging out (so to call it) of some of the beds towards the north, and a lessening in the thickness of some of the coal seams; hence it is not improbable that a larger number of coals are to be found south of the Ohio county disturbance than north of it. This is conjectural, however; and even should it prove true, it does not seem to have been effected by the disturbance—so far as the early history of the coal beds is concerned. This will become apparent further on.

It will be seen that each area has a certain individuality, which serves as a distinguishing feature, and that it is of sufficient importance to render the study of each section, by itself, desirable. Accordingly, the plan has been to limit the study of the geology of these districts less by the geographical than by the geological lines; so that the study of either section should not be confined to a single county, but would include such parts of the other counties as came within the geological bounds. With this in view, and in order that the report may be used in connection with, and properly form a part of, the record of the general results obtained in the study of the synclinal basin, only the southern part of Ohio county—somewhat more than half of the county—is now described.

I.

TOPOGRAPHY.

The topographical features of the district differ little from the general type presented in the interior portions of the western coal field. Soft sandstones and beds of shale of various sorts (usually sandy shale) are the elements from which have resulted a region of much flat land, a few prominent ridges, and occasional conical or flat-topped hills.

The accidents to which the crust has been subjected, viz: the disturbance along Rough creek, with its attendant twisting of the beds, and the uplift at the southern margin of the field, have impressed themselves on the geography of the region in a general way; but the chief features of the topography, so far as relates to details, have been determined by the simple erosion or wearing down of sandstones (usually incoherent) and sandy or clay shales, according to localities. The valley of Muddy creek, of Lewis creek in part, and probably of Rough creek, have been largely determined by dynamical agencies; but the character, both as to course and size, of the larger number of the drainage channels, has depended entirely on the character of the underlying beds and the various degrees of resistance with which they have withstood atmospheric effects. It is not uncommon to find instances where the course of a valley has been altered by the lateral passage of shale into sandstone, or *vice versa.* The effect, on the topography, of the few limestones which occur in the section, seems to have been very limited. In the region about Sulphur Springs, and eastwardly and westwardly from there, along Rough creek, the Sub-carboniferous limestones have given an area of occasional underground drainage, and produced somewhat of the peculiar topography we find when it is based on such beds; but the limestones are so intimately associated with sandstone and sandy shale, that the general features are still very largely those of what may be termed "sandstone topography." The area of the Sub-carboniferous limestones is also quite limited, being confined to a comparatively narrow strip along Rough creek.

The principal streams of the district, besides Rough creek, are Caney creek, Hall's creek, Mill run, Muddy creek, and Walton's creek—all of which are tributaries of Rough creek—Lewis creek, Bull's run, Slate creek, and Indian Camp creek (the head waters)—all of which flow into the Green river.

Chief among these streams are, (1) Caney creek, which flows into the county from Grayson county, and then flows northwardly, approximately parallel with the eastern boundary of the county; (2) Muddy creek, which flows in an irregular westwardly course, and empties into Rough creek about one mile and a half below Hartford, draining the region principally about Elm Lick and Rosine; (3) Lewis creek, which flows westwardly into the Green river, and drains the larger part of the southern portion of the district; and (4) Walton's creek, which drains the larger part of the region about Centretown, and flows northwardly into Rough creek.

The principal ridges of the district are three in number, and are, (*a*) one bordering on Muddy creek, south of the stream, (*b*) one lying farther to the south, whose southern slope is drained by Lewis creek, and (*c*) the "Jerusalem" ridge in the region of Rosine and Elm Lick, which is drained in part by Muddy creek. The general course of these ridges is north of westwardly. There are other ridges, especially north and northeastwardly from Elm Lick and Rosine, which are prominent features in the topography of the region, but their extent is usually short, and their courses quite irregular. The first ridge (*a*), which may be termed the "Muddy Creek ridge," is a low one, for the larger part of its course, and is comparatively short; it seems to coincide with the second ridge (*b*) towards the west, or to fall away and disappear in that direction; it has not been determined which condition occurs. Towards the east it breaks up in a series of rounded hills, which are washed by the numerous small tributaries of Muddy creek.

The second ridge (*b*) may be termed the "Coal ridge," as within it are contained the largest number of important coal beds to be found in any one ridge in the district. This ridge is apparently a part of the main ridge of the coal field, which has been mentioned in a preceding report,* and will be more fully discussed hereafter.

The Jerusalem ridge (*c*) is also an important ridge; but, although it contains a thick and important coal bed, does not have equal value, so far as concerns coal, with the "Coal ridge."

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*See part VII, volume IV, Kentucky Geological Reports, N. S. Shaler, Director.

II.

THE GENERAL STRUCTURE AND COURSE OF THE UPLIFT.

Naturally, one of the most interesting features in the structure of the district is the disturbance which forms its northward limit; hence the discussion of it will serve as a fitting introduction to the general account of the other features of the region. It is a line of uplift which stretches across the county in a somewhat irregular eastwardly and westwardly direction, extending to the Falls of Rough, and perhaps beyond, on the east; and through McLean county as far west as Sebree, in Webster county, and probably beyond.

The existence of the disturbance was discovered by Dr. D. D. Owen; but he does not seem to have recognized its full importance, or to have traced it for any distance, nor to have determined its nature.* He mentions it as the "Barnett's creek disturbance," probably referring to the region about the old salt wells, on Barnett's creek, and does not seem to have traced it any farther towards the east.

The disturbance was for the first time suspected by myself in March, 1874, upon a visit to a point on Rough creek, above Hartford, known as the "Iron Mountain." The discovery of Sub-carboniferous beds there, and the inclination of the strata, proved the existence of some sort of disturbance, but of what kind was not known. Another visit made to the locality in 1875, and the examinations, undertaken along the north and south running railways in the same year, proved the disturbance to have a considerable extent; but it was not until May, 1876, that its true significance and general character became apparent, and it was determined to be a line of uplift. The uplift is probably connected with the disturbance in Union county, described by Dr. Owen, and designated as the "Bald Hill disturbance."† This, however, is entirely conjectural, as that disturbance has not been studied as yet by any officer of the present Survey, nor the westward extension of this one fully determined.

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*See page 147, volume I, Kentucky Geological Reports, old series, D. D. Owen, Director.

†See page 112, volume I, Kentucky Geological Reports, old series, D. D. Owen, Director.

The location of the uplift is distinctly marked in the geography of the region by Rough creek, which, for the larger part of its course, closely follows the line of the disturbance, never permanently leaving it until within a few miles of the mouth of the stream; it does not, in fact, pass entirely beyond the limits of the uplift there. The detailed relations that exist between Rough creek and the disturbance cannot well be determined before the line of the uplift is accurately mapped; but all the evidence collected, so far, seems to indicate the date of the creek valley to be more recent than the disturbance, and that the course of the creek has been considerably influenced by the uplift. Although the disturbance is plainly an uplifting of the beds, and along some parts of its course is plainly an anticlinal fold, its general character, that which is most common throughout its length, is yet somewhat conjectural.

I am inclined to regard the uplift as an anticlinal fold, modified in its general character along some parts of its course. The balance of evidence favors such a classification; but as yet it must necessarily be a provisional one, as at some points the disturbance exists as a *fault*, while at some others the evidence seems to point to a *monoclinal fold*. So far as Ohio county alone is concerned, the disturbance may safely be regarded as (most commonly) an anticlinal fold; but as it extends far beyond the limits of this county, and must hereafter be considered in the relation it bears towards other parts of the coal field, it is desirable to avoid any name that may be too local in its application. Accordingly, from the relations existing between the disturbance and Rough creek, it is designated as the "Rough Creek uplift" in this and a preceding report.*

The course of the uplift varies considerably. The strike of

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*See *Report on the Geology of the Regions Adjacent to the North and South Running Railways*, part VII, volume IV, new series, Kentucky Geological Reports, N. S. Shaler, Director.

the beds ranges from north 40° east, in the vicinity of Hartford, to north 85° east (though more commonly north 70° east), in the region about Sulphur Springs and Barrett's Ferry, while west of Hartford the variation is from north 30° west to north 85° west—the strike of the beds at the old salt wells, on Barnett's creek, however, being north 55° west to north 65° west. We thus find an almost complete swinging around of the line of the uplift westwardly from Hartford.

There seems to be little room to doubt, that when the line of the uplift is accurately mapped, it will be found to be marked very faithfully by the course of Rough creek; for that stream seems to depend very largely on the turns of the line of the uplift for its more important changes of direction. The value that the uplift has in directing the course of the stream is curiously illustrated by the decided curve to the south made by the stream when north of Hartford, and the turn then made towards the north just after Hartford is passed. That this is very largely due to the changes in the course of the uplift becomes plain when a map (even a poor one) of the line of uplift is compared with a good map of the stream—which we fortunately have.

From "Clifty Hill," above Barrett's Ferry, to the Sulphur Springs, and a short distance beyond, the general direction of the uplift is about north 70° east; it then changes, and at half a mile south of west of the Sulphur Springs bears north 65° east, and keeps this general course for several miles towards the west. The course is then altered again, and bears north 40° east, at a point northwardly from Hartford.

On the lower Hawesville road, northwestwardly from Hartford, a good view of the tilted beds near the axis of the uplift is obtained; their strike bears about north 85° west. This is modified to north 30° west, still farther west, and is again changed in the vicinity of the old salt wells on Barnett's creek, the strike of the beds there being north 55° west to north 65° west.

It will be seen that the course of the line of the uplift forms somewhat of an open loop near Hartford—the open part of the loop being towards the north. The map of Rough creek shows the same feature in the course of the stream. This loop really represents a shallow synclinal in the vicinity of Hartford, as will be seen from the following: In the immediate vicinity of Hartford, and for some distance north of the town, the beds are found dipping nearly due west, the bearing being a little north of a due west course; but west of the town, on the west side of Rough creek, the dip is reversed, and bears south of east—in some places nearly due southeast—gradually, however, swinging around to the southwest towards Barnett's creek.

The existence of this synclinal may serve to explain the southwardly course of the stream from the mouth of Flat Lick to the mouth of Muddy creek, and its subsequent departure from such close connection with the uplift as exists eastwardly from Hartford. It cannot be said to ever pass entirely beyond the influence of the uplift, for there is a marked relation between the strike of the uplifted beds and the course of the creek, so far as it flows; but its channel is within a different set of beds from those on its upper course (which are the older), and the distance between the stream and the central line of uplift is increased. This seems to be due to the southwardly impetus gained by the stream when turned through the synclinal valley.

Northeastwardly from Hartford the beds, near the central line of uplift, are frequently exposed within short distances of Rough creek. On the Hartford and Sulphur Springs road, Chester limestone, overlaid by about forty feet of shaly sandstone, is exposed in the divide between Hall's creek and Sullenger's branch, about one mile from Hall's creek. Limestone of the same age is exposed in the region about the Sulphur Springs and Hines' Mill. In the vicinity of Sulphur Springs the limestone is frequently found toward the base of the hills, with massive sandstone above it.*

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*For the details of the structure of this region, and of all that eastwardly to the Grayson county line, the reader is referred to the forthcoming report of Mr. P. N. Moore on the Eastern Margin of the Coal Field.

Northeastwardly from Sulphur Springs a thin coal bed occurs, in close connection with what seems to be Sub-carboniferous limestone. The coal is about nine inches thick, and is probably at the base of the coal measures. The precise age of the limestone underlying the coal could not well be determined, but it seemed to belong to the Chester Group. The coal is covered by four feet or more of drab sandy shale, and is firm and glossy black. The beds seemed to be dipping at an angle of about 6° course south 25° east. This is on Mr. N. P. Boswell's land.

At Mr. T. J. Barrett's "Sulphur Lick," about two and a half miles north of east from the Sulphur Springs, a sandstone is exposed which is tilted apparently at an angle of nearly 45°. Very little of the bed could be seen, so that the angle of the dip may really not be so steep. Limestone is reported to have been found below the sandstone.

In the Hartford and Hardinsburg road (the old "Louisville and Hopkinsville" road), about half a mile a little south of east from the Sulphur Lick, sandstone, probably equivalent to that seen at the lick, is exposed. The bed is dipping about south 20° east, the strike being north 70° east. Chester limestone is exposed in the road about seventy-five yards northwardly from the sandstone outcrop, but is apparently nearly horizontal. Its place seems to be below the sandstone. *Spirifer increbescens* is very abundant in the rock.

About twenty yards beyond the limestone a thin seam of coal, six to seven inches thick, is exposed, with a dip reversed to that of the sandstone. There seems to be the axis of an anticlinal here. This place is near Barrett's Ferry.

At "Clifty Hill," on the north bank of Rough creek, about half a mile north 65° east above Barrett's Ferry, a fine view of the central structure of the uplift is obtained. Tilted beds of sandstone, shale, and Sub-carboniferous limestone are seen in the following order:

1. Massive limestone.
2. Space; notably sandstone and shale, which are probably crushed.

3. Massive compact sandstone.

The beds are tilted at an angle of 60°, so nearly as could be determined; course about south 20° east. The arrangement of the beds is shown in figure 1, plate I.

Chester limestone, overlaid by sandstone, is also seen in the Hartford and Hardinsburg road, about one mile and three quarters south of west from Barrett's Ferry. The beds at this place seem to be nearly horizontal. Farther to the west, at the crossing of Sulphur run, about one mile and three quarters south 50° east from Sulphur Springs, the Chester beds are again exposed—at the foot of the dividing ridge between Sulphur run and Hall's creek. As the road mounts the ridge rhomboidal blocks of sandstone are exposed, whose place is above the limestone. The beds are nearly horizontal. The lessening in the degree of the dip of the beds is plainly seen as we recede from Rough creek.

In the vicinity of Hartford lower members of the coal measures are exposed, which are affected by the dip of the Subcarboniferous beds to the north, but show a change in the direction of dip, as compared with that seen towards Sulphur Springs. At the "Foreman Riffle," on Rough creek, about half a mile above Hartford, shaly sandstone is exposed—the beds dipping apparently south 45° west. The precise direction is obscure, as the outcrop is limited.

At the "water" mill, at Hartford, higher beds are seen, consisting of sandstone, limestone, and coal, which have a considerable dip nearly due west. At the mill the inclination of the beds amounts to eight feet in one hundred and eighty feet. On the Hartford and Hawesville road, about five miles west of north from Hartford, Chester beds, consisting of sandstone, limestone, and shale, are exposed, inclined at a steep angle. At one place the sandstone shows a dip of 28°, course south 60° west; this, however, seems to be a local exaggeration, as the more trustworthy beds of limestone show a dip of only 15°, course south 25° west, which is probably the general inclination of the beds in the locality.

On Barnett's creek, on Mr. Lewis Turner's land, and in Mr. Stephen Woodward's field, near the "old salt wells," Sub-carboniferous limestones are exposed tilted at high angles.* On Mr. Turner's land the limestone, thirty feet of which is exposed, is inclined at an angle of 40°, course south 35° west. This place is about three and a half miles, by map measurement, above the mouth of Barnett's creek.

Such are the features to be observed in a general survey of the Rough creek uplift. The disturbance is certainly one of the most interesting problems to be found in the western coal field, not only in its scientific but economic bearings, and merits a more extended study than it has yet received.

III.

THE GENERAL STRUCTURE OF THE DISTRICT.

As intimated on a preceding page, the principal topographical features of the district south of the Rough creek uplift are a principal ridge, having a northwestwardly trend, which forms the water-shed for the waters of Lewis creek on the south, and the waters of Muddy creek in part, and of Rough creek in part, on the north, and a subordinate ridge to the north and south of the principal one; this is the "Coal" ridge. These, with the "Jerusalem" ridge, are the principal features; but they are not the only prominent ones. The "Ben's Lick hills," between Brush creek and Ben's Lick creek (both of which streams flow into Rough creek); a few conical hills on the borders of Muddy creek; the ridge down which flow the streams of Flat Lick, Mill Run, etc. (but which is very much broken, and is really connected with the ridge northwardly from Rosine), and the ridge at Point Pleasant and near Centretown, are also prominent, especially in their geological value.

The coal ridge, which, for the larger part of its course, lies south of the railroad, and extends in an irregular line from the head waters of Indian Camp creek to the Green river, with its various spurs, seems to contain not only a larger number of coals, but a larger area of thick beds than any of the other ridges.

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*This is probably the locality visited by Dr Owen; see page 147, volume I, old series, Kentucky Geological Reports, D. D. Owen, Director.

The Ben's Lick hills contain some of the thick beds; the Jerusalem ridge contains a bed from three feet ten inches to six feet six inches thick (including a clay parting), and within the ridge near Centretown, and at Point Pleasant, the thickest bed of coal in the district is found; but compared with that of the beds in the coal ridge, the area of the coals is small. The precise value, in beds of coal, of the coal ridge, cannot be determined until its form is accurately mapped.

The general slope of the beds from the Rough creek uplift is, east of Hartford, between 20° and 35° east of south; west of Hartford the direction, as indicated on a preceding page, is very variable, the general course, however, being southwestwardly. East of Hartford, the southwardly slope of the beds seems to terminate at the valley of Muddy creek, giving place thereat to a southwardly rise.

The region west of Hartford has not been studied sufficiently in detail for the precise limits of the various dips of the beds to be determined. The dip is not only very variable, but complicated by a small fault, which extends northwardly from Rockport, on the Green river. It may be said, however, that, in that region, there is a general retreat, to the northward, of the limit of the southward slope of the beds as the Green river is approached; that is, the line limiting the southward slope swings round west of Hartford and points towards the northwest, in the direction of the Green river.

It seems that, were these lines projected on a map, they would be found to represent an imperfectly formed letter V —one stem reaching out past Beaver Dam, Elm Lick, and Rosine, and the other one extending towards Point Pleasant, on the Green river — the angle being somewhere between McHenry and the Lewis creek tunnel.

South of these lines the strata rise towards the south. It will therefore be seen, that the larger part of the valley of Muddy creek is within a synclinal depression, the direction of which is northeastwardly. It seems, indeed, that the "Muddy Creek" ridge, at the base of which Beaver Dam stands, may be regarded as a synclinal one. It seems to be near the central axis of the great synclinal (so to call it) extending from the Rough Creek uplift to the southern border of the coal field.

NUMBER OF COAL BEDS AND THE GENERAL SECTION.

There seem to be at least eleven distinct coals within the district; but only ten have been fully identified. This does not take into account the coals towards the extreme eastern margin of the county, in which direction there is at least one bed lower than the ones enumerated in the following section, nor yet those lying closely along the uplift. So far, I have been unable to satisfactorily obtain the direct connection between these lowest coals and the ones lying above them, on account of the limited character of their outcrops, and the difficulty of tracing the strata—a difficulty which will be recognized by one who has worked in this coal field, where the beds are seldom horizontal for any considerable number of miles, and the structure is so frequently masked by disintegration of the rocks. I have accordingly preferred to limit the section more particularly to those localities where the element of dip would have the least bearing in the computation of the distances between the beds; where, indeed, the direct connection of one bed with another one could frequently be obtained, by simply descending from the one bed to the other, without passing over any considerable horizontal distance. In the region bordering immediately on the lower uplifted rocks, the dip, as mentioned on a preceding page, is quite variable, both in amount and direction. Farther to the south, however, where the slope of the beds is towards the north, the dip is more regular in amount, and more constant in direction; consequently, the relations between the beds are generally quite plain. In several instances, vertical sections of the ridges have shown as many as four coals in orderly succession, while many of the sections show from two to three coals following one another within short horizontal distances. The grouping of these sections, by the identification of some of the members of one section with corresponding ones of another, has resulted in establishing a general section showing a thickness between five hundred and six hundred feet of beds —including at least ten comparatively constant coals and one whose character is yet conjectural.

Even those coals that may be regarded as comparatively constant are not, however, presumed to be present everywhere that their horizons are reached. There seem to be at least two whose places are sometimes filled with sandstone or beds of shale; and the indications seem to be, that in the vicinity of Fordsville (which, however, is north of the northern limit of the synclinal basin) there is a shortening from the base upwards of the section, and an absence of some of the coal beds. Whether this is actually the case, however, is as yet problematical; and should it prove to be the case, the cause is as yet imperfectly understood. There is this to be said, however, in such a connection: at Fordsville, and on the extreme eastern margin of the district, the coal-bearing series rest immediately on the Chester (Sub-carboniferous) beds. At Fordsville, and near the Sulphur Springs, a thin seam of coal, which may possibly be Coal L, rests within a few feet (sometimes within a few inches) of the Sub-carboniferous limestone.* This is to be observed at Spring Lick, in Grayson county, and further east. At Spring Lick, Coal L occurs at five feet above the Chester limestone.†

Towards the southern border of the field, in Butler and Muhlenburg counties, a conglomerated sandstone, known simply as the "Conglomerate," lies at the base of the coal measures, and is interposed between the lowest coal and the Sub-carboniferous beds. The same conditions as those to which the Conglomerate owes its presence on the south, while it is absent towards the east and on the northern limits of the synclinal basin, may have been of value in determining the distribution of the coal beds.* This is to be regarded merely as a suggestion.†

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* For a full discussion of the section at Fordsville and surrounding region, see the forthcoming report of Mr. P. N. Moore, hitherto mentioned.

† See page 54, part VI, volume I, Kentucky Geological Reports, new series, N. S. Shaler, Director.

All things being considered, the evidence as to the apparent shortening up of the section, and the decrease in the number of coal beds in the direction of Fordsville, is of a nature too imperfect for the basing of any conclusion upon it. Any absence of beds that should be proved to occur in that direction might be due to such local accidents, comparatively limited in their operations, as are known to have occurred in connection with some of the beds in the more central part of the coal field.

Such suggestions as have been made in regard to the shortening up of the section, or diminution in the number of coal beds, are not, therefore, to be regarded as conclusions based on well-worked out facts, but as suggestions of the conditions possibly existing. It is only when the region is worked out carefully in detail that the problem will find its solution.

The following is a general statement of the beds in the synclinal basin;‡ it is a generalization of about forty local sections, besides the more general observations:

GENERAL SECTION.

No.	DESCRIPTION OF STRATA.	Feet.	Inches.
1	Sandstone, the "Anvil Rock."		
2	Shale.		
3	*Coal A*	5	
4	Shale	. . .	6
5	Limestone	1	6
6	Shale . . . . 0 to	2	
7	*Coal B*	6	
8	Under clay	2	
9	Sandstone . . . . { This space is sometimes filled with a single massive sandstone. } . .	25	
10	*Coal;* not always present (C?)	. . .	3
11	Sandy Shale and Sandstone	30	
12	Bluish Shale, with ochre concretions . . .	25	
	Carried forward	97	3

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*This question is probably discussed in the Biennial Report of the Director of the Survey.

†Some fragments of Conglomerate have been found near the line of the Rough Creek uplift, but have not yet been traced to a bed *in situ*.

‡The regions about Centretown and to the west, and that about Point Pleasant, are excepted, for reasons which are given on another page.

GENERAL SECTION—Continued.

No.	DESCRIPTION OF STRATA.	Feet.	Inches.
	Brought forward	97	3
13	Bituminous Slate 2 feet to	4	
14	Pyritous band filled with fossils; not always, though usually, present	. . .	2
15	*Coal D* 5 feet 7 inches to	4	8
16	Under clay; frequently contains an irregular bed of concretionary masses of light blue, smooth-grained limestone	3	
17	Sandstone and shale 45 feet to	50	
18	Bituminous Slate containing fish scales 3 feet to	5	
19	*Coal E;* sometimes divided into several members 16 inches to	1	6
20	Space; notably shale	17	
21	Grey Limestone; may not be precisely in place	2	
22	Space; notably sandstone and shale	10	
23	Black Slate, filled with fish remains 18 inches to	3	
24	*Coal* E^a 14 inches to	1	8
25	Under clay	3	
26	Soft disintegrating Sandstone. This is frequently a mixture of shaly disintegrating sandstone and sandy shales { This space is sometimes increased to 40 feet, and filled with soft sandst'e. }	27	
27	Space; sometimes filled with reddish clay	5	
28	Bituminous Slate 0 to	1	6
29	*Coal F* 9 inches to	1	6
30	Under clay 0 to	3	
31	Mottled dark drab and ashy-grey or white, impure Limestone. Has frequently a brecciated appearance on the surface, and is sometimes somewhat nodular on top. Weathers a brown or ferruginous tinge. Contains *Spirifer* (*Martinia ?*) *lineatus*, *Martinia plano convexus*, and *Rhombopora lepidodendroides* 1 foot to	2	2
32	Shale	20	
33	Sandstone and shale { This space is sometimes filled with a massive sandstone 65 feet thick. } 20 feet to	35	
34	*Coal G*	1	2
35	Sandstone and shale	30	
36	Blue, shelly earthy Limestone. In places has somewhat of a concretionary structure near the middle of the bed. Breaks with an irregular fracture. Organic remains are abundant, including *Productus muricatus*, *Prod. Pratteniatus*, *Prod. Nebrascensis ? Spirifer cameratus*, *Athyris Subtilita*, *Aviculopecten* ——*? Chonetes mesoloba*, etc.	6	
37	Dark calcareous Shale, containing numerous small calcareous concretions; merges above into No. 36, and below into No. 38. Contains *Productus muricatus* and *Chonetes mesoloba* in the lower part	7	6
38	Impure, coarse-grained, dark grey crinoidal Limestone	. . .	
39	Argillo-calcareous material. Somewhat of a shale. Is filled with *Productus muricatus*, especially at the bottom	1	
40	Black Shale interlaminated with thin streaks of coal	. . .	1½
41	*Coal* 11 inches to	1	6
42	Under clay. This is dark grey and very impure, specks of charcoal and small concretions of pyrites being abundant in it. Base not seen	1	
43	Space, mostly filled with argillo-sandy shale	7	
44	Hard Chert, usually in rhomboidal blocks. Color, yellow and dark. Usually abounds in *Fusulina cylindrica*, and may be identified as the "*Fusulina Chert*"	. . .	6
45	Shaly Sandstone, or argillo-sandy shale 10 feet to	20	
46	*Coal* 16 inches to	2	7½
	Carried forward	376	8

GENERAL SECTION—Continued.

No.	Description of Strata.	Feet.	Inches.
	Brought forward	376	8
47	Space; mostly Sandstone . . . . . . (This space varies from 40 to 70? feet, and is sometimes nearly all sandstone.)	30	
48	Argillaceous Shale .	10	
49	The "*Elm Lick Coal*" divided by a clay parting thus: *a.* Coal . . . . 18 inches. *b.* Clay . . . . 4 to 18 " *c.* Coal . . . . 36 "	6	
50	Space	5	
51	Massive Sandstone	35	
52	Shale	5	
53	*Coal* . . . . 22 inches to	2?	
54	Space	46	
55	Sandstone and shale	7	
56	Sandstone, soft and disintegrating	12	
	Total	534	8

It will be seen in the above statement, that the distances are sometimes considerably modified. The observations have not been sufficient to determine the most common distances between such beds, nor the character of the materials most generally filling the spaces. This is especially true of the spaces between the limestones No. 31 and No. 36, and between the Fusulina chert and the coal No. 49.

In the vicinity of Cromwell (as at Greenville, in Muhlenburg county), a coal bed of fourteen inches in thickness (No. 34 of the section) occurs at fifty-five feet below the "mottled limestone," No. 31—the space between being filled with shaly sandstone and shale. In the neighborhood of Mr. L. D. Taylor's, however, the section is shortened, the coal No. 45 being only one hundred feet below the mottled limestone, the probabilities being that coal No. 34 is not present. Near Mr. James Raley's the coal No. 34 is evidently not present, as a massive sandstone sixty-five feet thick occurs at twenty feet below the limestone; the sandstone also appears either to cut out the beds from No. 35 to No. 44, or to considerably lengthen the section. This is shown on plate 2.

The space between the Fusulina chert (No. 44) and the Elm Lick coal is also variable, and the standard distance has not been fully determined. Barometrical measurements* have been made, which seem to show a variation in the distance from about fifty to seventy feet. The amount of variation seems to depend on the thickening or thinning of a soft massive sandstone, which underlies the first coal below the chert. The sandstone seems to vary in thickness from thirty to fifty feet, and thus causes the distance between the two coals to range from about thirty-five to fifty feet. It is not improbable that this sandstone cuts out the coal occasionally; of this, however, the evidence is not satisfactory.

The space between the Fusulina chert and the first coal below it (No. 46) varies comparatively little. It is probable that the coal will very generally be found at about twenty feet below the chert.

It will be seen that the lower part of the section undergoes considerable changes in the several parts of the district; accordingly, the record from bed No. 34 to bed No. 53 must be regarded as somewhat preliminary in character, until sufficient data have been obtained to warrant a final revision of the statement, and a determination thereby of the standard distances between the coal beds.† The expediency of this will become apparent hereafter.

From coal A (No. 3) downwards to coal F, however, the distances given in the general section seem to be comparatively constant; accordingly, that part of the section may be considered as generally applicable over the district.

It may also be well to state, that Coal G is, so far as at present known, more frequently found than not, at about forty feet below Coal F.

DESCRIPTION OF THE BEDS.

The larger number of the prominent beds of the section are so fully marked by their individual characters, that their identification is easy; some of them, however, are to be identified only by the beds found associated with them.

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* These are without correction, as I was without facilities for checking them.

† This work is now in hand.

The "Anvil Rock" Sandstone.—As is mentioned in a former report* (in which it is fully described), this sandstone received its name from Dr. D. D. Owen. It is to be identified only by its relative position towards other beds. So far as relates to this county alone, there is little to be added to the descriptions of the rock which have already been published. Observations which have been made in Muhlenburg county, however, tend to prove the accuracy of the suggestions formerly made as to the probability of the sandstone being conglomerated in some localities.†

Coal A.—This bed is very seldom wrought in the county, as its extent, as a workable bed, is limited to small areas. Unless it is in the region about Point Pleasant and Centretown, the deposit seldom reaches any considerable thickness. This, in a large measure, is due to the high position it occupies in the section, which usually brings it so near the tops of the hills that the coal wastes away under the action of the weather. The place of the bed is frequently only indicated by a dark earth or by its stained "under clay."

The inconstancy of Coal A has been pointed out in a former report,‡ and was referred, in part, to the varying conditions which no doubt existed during the deposition of the Anvil Rock sandstone; but the examinations in this district have seemed to show, at some points, the absence of Coal B when Coal A was present. This, however, is not fully proven, as in every case where such conditions seemed to exist the section was not fairly exposed.

Coal B.—This bed has been fully described in a preceding report.

It is probable that in the region about Hamilton, McHenry, and Rockport, the coal may be found in a workable condition. It is worked at Paine's mines, on the river, opposite Rockport, and at Airdrie, farther up the river. The bed is not found east of Beaver Dam, and its place in the ridge south of that place is only indicated by a black "dirt." Much that has been said concerning Coal A may be applied to Coal B in this district.

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* See part VI, volume I, new series, Kentucky Geological Reports, N. S. Shaler, Director.

† See part VII, volume IV, new series, Kentucky Geological Reports, N. S. Shaler, Director.

‡ Part VI, volume I, new series, Kentucky Geological Reports, N. S. Shaler, Director.

Coal D.—This bed has also been described sufficiently well in a former report. Since the publication of that report, however, the coal has been found showing a larger thickness than was reported therein.

On Mr. Alfred Brown's land, one mile and a quarter about south 10° east from Beaver Dam, the coal has been opened, showing a thickness of five feet seven and three fourths inches. The usual thickness of the bed is four feet eight inches. The coal is covered by a slabby bituminous slate, which frequently contains large pyritiferous concretions, and this is usually overlaid by bluish argillo-sandy shale, containing ochreous concretions. In some places, however, the slate is immediately overlaid by a massive sandstone, fifty to seventy feet thick, as at the old Taylor mine on the Green river, below Cromwell.

Coal D seems to be the most trustworthy coal in the district, but its area is irregular in form. So far, the observations seem to prove the bed to be confined to the region south of Rough creek. Its eastern limit would be marked by an irregular line drawn from near the mouth of Ben's Lick run, on Rough creek, in a southeastwardly course to Kate's Hill, on the Hartford and Morgantown road, southeastwardly from Beaver Dam; thence it extends, with a westwardly curve, to the old Taylor mines, on the Green river, passing west of Cromwell and Pinchico. There are probably some exposures of the coal east of this line in the southern part of the county, but they are quite detached, and occupy comparatively small areas, although some of them may doubtlessly be extensive enough to supply a mining company for years with coal. The line indicated undoubtedly marks the eastern limit of the coal as a solid sheet.

South of Lewis creek, the beds sink towards the west, so that Coal D may be regarded as underlying the larger part of the region included between the Green river and the imaginary line to the east, except that part towards Rochester. In the vicinity of Rochester lower coals are the first ones beneath the surface.

North of Lewis creek Coal D does not seem to have so wide an area, at least not as a continuous sheet. It seems to underlie only a somewhat triangular area in the region between Clear run and Ben's Lick run, known as the "Ben's Lick Hills," reaching not quite to Clear run; and then to be absent for a considerable distance to the west, on account of both the geological and topographical conditions.*

In the region to the west the position of the coal is affected by the small fault which courses northwardly from Rockport. The coal, under other conditions, has a northwestwardly rise from Miller's bank (in the Ben's Lick Hills); but the Rockport fracture† having occurred since(?) the beds were raised in that direction, the coal has been let down about fifty or sixty feet towards the west along that line of fracture, and towards the Green river the direction of the rise of the beds is changed to about north 40° east. In consequence of these conditions, Coal D seems to be deep-seated in the region between Rockport and Point Pleasant.

Coal E.—This coal has been the source of some confusion, not only to myself, but to the officers of the first Survey. There is no doubt that this bed, and the one lying immediately below it, were confounded with each other—their slates being so nearly alike, and the distances between them so short—and the two referred to a single bed. The investigations of the past season prove the existence, beyond a doubt, of two beds instead of one, one of which, without doubt, corresponds to Coal E of the nomenclature adopted in the preliminary work of the present Survey, or No. 8, according to the numbering used by Dr. Owen. The other bed may, for the present, be designated as Coal E^a.

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*In volume III, page 543, of the first series of Kentucky Geological Reports, a coal, which is exposed in the left bank of Rough creek, at Hartford, was identified as Coal D ("No 9"). But, as shown in a former report, that coal is a lower bed. Coal D, as shown on a succeeding page, is worked in the Ben's Lick Hills, and is plainly above the bed seen at Hartford, even measuring the height by its topographical position alone.

†Described on a succeeding page.

In the report on the geology of the region adjacent to the Louisville, Paducah and Southwestern Railroad, the conclusion is given that Coal E is very untrustworthy. This statement was, of course, based on the impression that only one bed occurs in the space in which two are now known to lie, and which were confounded with each other. The more recent observations have shown the possible necessity of modifying the statement as to the constancy of the bed; but there is no reason to question the accuracy of the conclusions as to the general thickness, and the value of the coal for industrial purposes. It has nowhere been found sufficiently thick to be mined with profit.

The coal is usually overlaid by a thick deposit of dense, black bituminous slate, which breaks into slabs, and in which a few fish scales and spines(?) are found. The fish scales are peculiar in form, but alone do not serve to identify the slate, as the slate covering the lower coal is much more abundantly filled with them. For a perfect identification of the bed, in a case where one is unacquainted with those peculiar characters that may be observed in a certain coal, but not described, and are to be known only through practical experience with the bed, it is necessary either for the whole or a large part of the coal and its roof of slate to be exposed, or for some one of the coals associated with it to be exposed in the vicinity. The distance from the base of Coal D to the top of Coal E is from forty-five to fifty feet.

The following is a section of the bed as exposed on Mr. Poyner's land, southeastwardly from Beaver Dam; it may serve as an example of the conditions usually presented by the coal in this district:

No.	Description of Strata.	Feet.	Inches.
1	Black, hard, slabby bituminous slate	3	
2	Drab clay, rather hard	. . .	5½
3	Coal and clay . . . } . . . . 1 inch to	. . .	1½
4	Clay . . . . } 14 inches . . . . ½ inch to	. . .	1
5	Coal, base not seen. } . . . . said to be 1 foot to	1	2

The most trustworthy features to be observed in connection with this coal, and to be used as means for its identification, seem to be the extraordinary thickness of the black slate overlying it, the thickness of which sometimes measures five feet, the occurrence of the peculiar fish scales and spines(?) in the slate, and the clay divisions in the coal. The fish remains seem to be peculiar to the slates over Coals E and E^a, being, however, more numerous in the slate over the lower coal, which slate is also to be distinguished from the one overlying Coal E by its being less dense, and usually not more than half so thick.

Coal E extends over a wide territory. It lies near the surface east of Beaver Dam, in the region about Liberty Church, near Hartford, Cromwell, and Pinchico, and may safely be presumed to underlie all that area in which Coal D is present.

Coal E^a.—This bed normally occurs at twenty-five to thirty feet below Coal E. It is probably the one most often mentioned as Coal 8 in the reports of the first Geological Survey (although there is no doubt that the upper bed was also identified with that number), and is the one generally regarded as Coal E in the report on the coals along the line of the Louisville, Paducah and Southwestern Railroad.*

On account of reasons which it is now unnecessary to enumerate, the identity of this coal, as distinguished from the one now designated as Coal E, was not discovered when the region was examined for the first time.

The coal varies from fourteen inches to twenty inches in thickness, and is covered by two feet of usually hard, frequently polished, bituminous slate, abundantly filled with fish scales and spines(?). An occasional fish tooth, *Peripristis semi-circularis*, is also found in the slate; but teeth are rare. The slate is not always hard nor polished, but is sometimes dull black and quite fragile. The character and fossil contents of the slate serve as very fair means for identifying the coal.

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*This bed was also identified as No. 7 at some places by officers of the former Geological Survey.

Coal E^a probably has an area equal to that of Coal E, if not a larger one. It should be stated, however, that neither bed is frequently exposed in the county; other beds concealing them, or the topographical conditions being unfavorable.

Coal F.—When this district was first traversed this bed was not observed, the space seeming to be completely filled with sandstones and shales. The more general examinations made during the past season have proved the presence of the coal over a large part of the district.

The thickness of the coal varies considerably, ranging from nine inches to eighteen inches; but its horizon is well marked, and it may be identified wherever the topographical conditions and the positions of the beds are favorable.

As a surface bed, it is most frequently exposed in the region near Cromwell and about Liberty Church, its outcrops seeming to be chiefly limited to the ridge forming the water-shed for the waters of Lewis creek, Indian Camp creek, Slaty creek, and Muddy creek.

The place of the coal is marked by a peculiarly mottled drab-colored and ashy-white limestone, varying in thickness from twelve inches to twenty-six inches, which is described as No. 31 in the general section. This bed is the equivalent of the mottled limestone seen at Greenville, and probably of the upper "impure limestone" indicated in the Airdrie section, as given by Dr. Owen.* Its identification in this district proves the extent of the bed to be greater than was suggested in my former report.

Coal G?—This bed was also observed for the first time, in this district, during the last summer (1876). It was formerly presumed not to be present far beyond the Green river, in an easterly direction. Its precise character is still conjectural, as the bed was observed at only one place in the county, near Cromwell, and was then seen only as a coal "dirt." The general extent of the coal is accordingly unknown, but the bed seems to be irregular in extent, or, at least, to be interrupted by sandstone at some places.

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*See page 25, volume III, Kentucky Geological Reports, old series, D. D. Owen, Director.

Number 36—*Limestone.*—The principal outcrops of this limestone are in the region bordering Rough creek. As stated on a preceding page, it seems to be cut out, and its place filled with sandstones and shales, in some parts of the district; it is so earthy in composition, however, and disintegrates so readily upon exposure, that, in some cases, the limestone is probably merely concealed by débris, chiefly the result of its own disintegration, instead of being absent. In some places it seems to be represented only by a cellular, apparently somewhat silicious, yellow limestone, or calcareous mass, abundantly filled with *Productus muricatus*, which is immediately underlaid by the coal No. 41 of the section.*

Number 41—*Coal.*—This bed has been observed at but few places, its horizon usually being covered. It is exposed at the water's edge at the water-mill at Hartford (where its thickness is eleven inches); on the Hartford and Morgantown road, by the former residence of Col. O. P. Johnston (now owned by Mr. Williams), and on the land of Mr. J. B. Bennett, on the Hartford and Livermore road. Little more is known concerning the coal. It is possible that it may prove to be a bed of some value when more fully studied.

Number 44—*The "Fusulina Chert."*—This bed, or rather the débris of it, is more frequently found than the blue shelly limestone, which occurs above it. It seems probable that, in some places, it is present and the limestone not; but this has not been proved.

The chert is easily recognized by the large number of *Fusulinæ* contained in it. The chert was seldom found in a compact bed, hence its general thickness was not determined; in a few places it measures six inches. Few fossils, other than the *Fusulinæ*, were found in it.

Number 46—*Coal.*—This coal seems to be fully as persistent as any of the beds below Coal D. It has never been found fairly exposed, its place usually being indicated by a stain or a "dirt." At one place, however (at Mr. L. D. Taylor's), the bed has been opened sufficiently to expose a hard, good-looking coal thirty-one and a half inches thick. In some localities the bed seems to have a clay parting.

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*A fuller account of this limestone, and its general relations, which are important, will be given in another report.

It has been found on the Hartford and Morgantown road, near Col. O. P. Johnston's former residence, where its outcrop measured eighteen inches; at Mr. L. D. Taylor's, as mentioned above; on Dr. Berry's land, on the Morgantown road, about three miles and a half from Hartford, and on the William Hines tract of land, now owned by Messrs. Walker and Berry, about four miles and a half or five miles about south 80° east from Hartford. The place of the coal is indicated by the presence of the Fusulina chert at a number of other points in the district, viz: on the old Nall tract of land, now owned by Hon. E. D. Walker, two and three quarters miles about north 70° east from Hartford, by the spring near the house; on land belonging to the heirs of Mr. Richard Stephens (deceased), on the Morgantown road, three miles from Hartford; on Mr. Spangler's old place, near Beaver Dam, towards Elm Lick; in Mrs. Barnett's lane, about one mile westwardly from Hartford, etc.

Number 49—*The Elm Lick Coal.*—This coal is one of the most important beds in the district. It is the one which has been wrought at the Martin bank, about one mile westwardly from Elm Lick; at Mr. Otto's and Mr. Chiles' banks, near Rosine; the one which is now wrought occasionally at the bank on Hon. E. D. Walker's land, known as the "Hines bank," and at banks belonging to Mr. Henry Thomson and Mr. George Neighbors, in the region south of Elm Lick. It may be the coal opened on Mrs. Charlotte Barnett's land, near the Hartford and Owensboro' road, about three miles from Hartford; this, however, is conjectural, as the bed wrought there was not exposed at any time when the place was visited, and the descriptions given concerning it vary.

The coal seems to be, very generally, what is known among miners as a "split vein." It is parted into two members by a clay seam, varying in thickness from three inches to eighteen inches. It may not be the rule, but, so far as observed, the thickness of the clay parting increases from the north towards the south. At the "Hines bank" it measures four inches, at the Martin bank six to nine inches, at the Chiles bank seventeen and one fourth inches, and at the opening on Mr. Henry Thomson's land the clay is from twelve to eighteen inches thick.

Following are sections of the bed which illustrate its general features in regard to thickness:

Name of bank.	Hines bank.		Martin bank.		Chiles' bank.		Thomson's bank.	
Thickness.	Feet.	Inches	Feet.	Inches	Feet.	Inches	Feet.	Inches
Upper member	1	. . .	1	6	1	9	1	5
Clay	. . .	4	. . .	6	1	5¼	1	6
Lower member	2	6	3	2	?	. . .	3	5
Total thickness	3	10	5	2	?	. . .	6	4

The upper member is usually poor, frequently being quite pyritiferous. As an average, it contains about 2 per cent. of sulphur. The lower member is very fair coal, though rather soft, and contains, as an average, about 1.8 per cent. of sulphur.

This bed will probably prove to be one of the most profitable coal deposits in the district.

Number 53—*Coal.*—Very little is known concerning the character and general extent of this bed. It was identified only at Mr. Jesse B. Mosely's, two miles and three quarters southwardly from Elm Lick; at Mr. L. L. Taylor's(?), half a mile eastwardly from Mr. Mosely's, and at Mr. Black's spring(?), about one mile and a half about northwest from Elm Lick.

A coal was seen at Mr. James Stewart's spring, about one mile nearly due south from Thomson's bank, which may prove to be the equivalent of this bed. It has a clay parting, and measures as follows:

a. Coal	12	inches.
b. Clay	2½	‘‘
c. Coal	6	‘‘
Total thickness	20½	‘‘

At the time the locality was examined, it was thought that this bed (at Stewart's) was probably the southern extension of the one seen at Mr. Thomson's. But for this to be true, there must be either a local dip of the bed to the south in that region, amounting to thirty feet in the mile (provided the measurements for vertical distance are correct*), or a fracture, extending eastwardly and westwardly, south of the Thomson bank—allowing the beds to drop a distance of thirty feet south of that line; neither of which conditions is clearly indicated.

As stated on a preceding page, that part of the general section included between No. 34 and No. 53 is to be considered as, in a certain degree, preliminary to the general summing up of the facts concerning the whole basin, and, for the present, it serves rather as a basis to work from than as a fully determined conclusion. Accordingly, the relations existing between certain of the beds are given as they are now understood, but with the provision that it may become necessary to revise some of the present conclusions.†

There are some beds of coal which may not be represented in the section, as the conditions surrounding them were such that, although, as at Mr. C. W. Stephens', one of the coals was easily identified with another well-known bed, the general relations of the ones associated with it were not sufficiently clear for an attempt to be made to identify them. A comparison of the section at Mr. Stephens' (see plate VII) with sections at other places, containing some equivalent beds (see plates VI and VII), will make the reason of this apparent.

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*Which were made with an uncorrected aneroid barometer, and, in consequence, are not entirely free from possible error.

†It must be understood, however, that any revisions that may become necessary will relate more particularly to the vertical distances between some of the beds than to the identification of them. It is also to be borne in mind, that the total number of beds of coal will not be affected thereby.

Plates II to VII, inclusive, present the local sections upon which the general section was founded, and of which descriptions will be found in the special account of localities.

The following is a table of analyses, made by the chemists of the Survey, of the samples collected from several of the coal beds of the county:

	1	2	3	4	5	6	7	8	9	10
Moisture	5.54	3.94	4.80	4.80	3.50	3.34	3.50	3.30	4.80	5.10
Vol. combustible matters	35.66	37.86	33.70	35.60	36.30	35.84	35.00	36.76	35.80	30.70
Fixed carbon	48.88	50.48	68.76	49.66	50.92	54.36	52.50	52.60	45.20	54.24
Ash	9.92	7.72	9.24	9.94	9.28	6.50	9.00	7.34	14.20	9.96
Sulphur	4.199	3.128	3.364	3.180	3.524	3.826	3.390	2.604	3.015	2.164
Specific gravity	. . . .	. . . .	1.386	1.356	1.345	1.315	1.421	1.316	1.384	1.382

	11	12	13	14	15	16	17	18	19
Moisture.	6.66	3.96	4.80	6.54	3.70	6.00	5.30	6.80	2.70
Volatile combustible matters . .	33.64	40.50	41.00	37.92	36.64	34.30	45.70	32.40	39.30
Fixed carbon.	51.56	52.38	49.14	51.54	55.30	50.36	45.00	52.50	45.90
Ash	8.14	3.16	5.06	4.00	4.36	9.34	4.00	8.30	12.10
Sulphur	2.768	3.128	2.356	1.917	1.241	4.307	2.150	2.109	7.959
Specific gravity	1.357	1.282	1.295	1.305	1.321	1.387	1.273	1.340	1.413

Analysis No. 1 is of samples taken from Doering's mine, near Centretown; 2, from Morton's mine, in the same locality; 3, from L. M. Patterson's mine, at Mt. Pleasant; 4 (Coal D), from Brown's bank, in the Ben's Lick Hills, near Hartford; 5 (Coal D), from Williams' bank, near Hartford; 6, the Taylor mine; 7, the Rockport mine; 8, Stephens' mine, near Beaver Dam; 9 (Coal E), from the bank of Rough creek, at the mouth of Brush creek; 10, from M. Sandifur's bank; 11, from Wm. Warden's, half a mile northwest from Centretown; 12, Henry Thomson's bank (the Elm Lick coal); 13, Wm. Hines' bank, sample taken from below the parting in the coal (the Elm Lick coal); 14, same locality, from above the parting; 15, Martin's bank, from the lower member (the Elm Lick coal); 16, Berry and Walker's land, in ravine draining into the North Fork of Muddy creek, near the Hines bank; 17, "old opening" on Berry and Walker's place, near the Hines bank; 18, from L. D. Taylor's bank; 19, from A. Woodward's coal.

IV.

LOCAL OBSERVATIONS.

In order to avoid repetition in the "County Report," which is to follow hereafter, it is deemed inexpedient to give, at present, more than an outline of the local examinations made in the county.

As stated on a preceding page, the beds are so disposed, by disturbances in the county, that there is a descent in the order of the series, from Beaver Dam towards Cromwell on the south, and towards Hartford on the north.

In the region about Hartford the beds have been moved by local disturbances (as mentioned on page —); but, as compared with the series in the more southerly part of the county, they have, nevertheless, a northwardly rise.

This arrangement of the beds naturally tends to throw the higher coals along the central part of the district, as is shown to be the case in the "Coal Ridge" and the hills in its vicinity. The higher coals are not, however, confined to such a position, but, where the topographical conditions are favorable, they are found (frequently as isolated masses) both to the north and to the south.

At the old Taylor mine, on the Green river, about one mile below Cromwell, and at Cromwell and in its vicinity, there are, collectively, six coals, the uppermost coal that is distinctly exposed being Coal D, which is the bed formerly worked at the old Taylor mine.* On the hill above the drift, at the Taylor mine, fragments of the limestone which occurs between Coals A and B are found, but no traces of the coal beds have yet been discovered.

The following is the general section of the beds at the mines, and at Cromwell and vicinity:

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*This place is mentioned on page 158, volume I, first series Kentucky Geological Reports, D. D. Owen, Director.

No.	Description of Strata.	Feet.	Inches.
1	Massive Sandstone	65	
2	*Coal D* (varies in thickness)	4	
3	Space	10	
4	Thin-bedded Sandstone	10	
5	Space	32	
6	Black Bituminous Slate	5	
7	*Coal E*	out	crop.
8	Space	25	
9	Black Slate, exposed for	2	
10	*Coal E*^{a}	out	crop.
11	Space	10	
12	Shale, containing iron-stone concretions	25	
13	Space, about	5	
14	*Coal F*	. . .	6
15	Space	2	
16	Mottled Limestone	1	
17	Space; notably shale, sandstone and shale	55	
18	*Coal G* . . . . . 1 foot to	. . .	9
19	Shale	35	
20	Black(?) Slate?	4	
21	*Coal;* below the level of the river	1	6
22	Under clay	4	
23	Shale	16	

The mottled limestone and associated beds are exposed frequently between Cromwell and Kate's Hill, on the Morgantown road, towards the railroad. They are also exposed in the region about the Bald Knob Church, on the Pinchico and Caney precinct road.

Near Bald Knob Church, in the road, by the dwelling of Mr. Robinson (on the farm of Rev. B. F. Jenkins), the following section is exposed:

No.	Description of Strata.	Feet.	Inches.
1	Covered space, red clay on the surface	5	
2	*Coal F*	. . .	9
3	Under clay	3	
4	Mottled Limestone; has a brecciated appearance on the surface	1	
5	Sandy Shale and Shaly Sandstone	28	
6	Mostly covered; notably Sandy Shale	8	
7	Soft disintegrating Sandstone	35	

By the Bald Knob Church the coal is again exposed, with an admirable fire-clay below it. The following is the analysis of the clay:

Silica	62.760
Alumina	26.420
Oxides of iron and manganese, and phosphoric acid	1.580
Lime	.325
Magnesia	trace.
Potash	.916
Soda	.268
Water expelled at red heat and loss	7.731
Total	100.000

On A. H. Davis' land, half a mile about south 70° east from the Bald Knob Church, a limestone higher than the mottled limestone occurs. It is probably a comparatively local bed. It is coarse, granulated in texture, and grey in color. A number of fossils were found in it, among which the following species were identified: *Productus muricatus*, *Athyris subtilita*, *Spirifer cameratus*, and *Crinoid* columns. A poor, argillaceous iron ore was seen resting, in places, above the limestone. It also is fossiliferous, and may accordingly be presumed to be nearly, if not quite, as extensive in area as the limestone. The ore, in fact, seems to be derived from the limestone. The mottled limestone is exposed below in the hill-side, about two hundred and fifty yards away from the upper bed. We accordingly have a very good level (in these two beds) from which to work when examining the structure of the contiguous region. The upper limestone does not, however, appear to be constant. It is, perhaps, probable that it is developed most fully in the region just now under consideration, and is not to be found, as a rule, outside of a restricted area. Of this, however, the evidence is limited.

On lands belonging to Mr. L. D. Taylor and Mr. F. M. Gillstrap, about one mile north 85° east from Bald Knob Church, a coal is found at a level below the mottled limestone; the cherty limestone containing *Prod. muricatus* is also exposed. The connection between the upper and lower part of the section is probably to be obtained more easily in this vicinity than elsewhere in the county.

The following is the section of the beds exposed here:

No.	Description of Strata.	Feet.	Inches.
1	Granular Grey Limestone, about	2	
2	Space	35	
3	Mottled Limestone	2	
4	Space . . . 70 to	80	
5	Fossiliferous Limestone and Chert	1	
6	Argillaceous Shale	20	
7	*Coal*	2	7½

By correlating this section with the ones obtained at Kate's Hill and in the vicinity (near Beaver Dam), we obtain a very fair knowledge of the arrangement and number of the beds from the summit downwards, for about three hundred and twenty-five feet.

The coal, No. 7 of the section, seems to be the equivalent of one to be seen, when the water is low, in the bank of Rough creek, at the Hartford water-mill. Between the lower cherty limestone and the mottled limestone a massive, incoherent sandstone occurs, filling up the larger part of the space.

From the region about Bald Knob Church, towards Beaver Dam, the beds sink towards the northwest.

The mottled limestone is seen occasionally along the Hartford and Morgantown road, south of the railroad, plainly showing this feature. Beyond the railroad the beds soon begin to rise.

On Kate's Hill the mottled limestone makes its last appearance south of the railroad. The general section of the strata forming Kate's Hill, and the ridge in which the coal banks of Mr. Albert Brown, Mr. Poyner, Mr. Stephens, Mrs. Austin, and the Taylor coal mines are opened, shows the beds from Coal A downwards to the sandstone below Coal F. The connection between the beds is very plain.

On Mr. Brown's place Coal D is especially well developed, being five feet seven and three fourths inches thick. Its usual thickness is four feet eight inches. Coal E is found at forty-five feet below Coal D, and is to be traced on to Mr. Poyner's land, where a still lower coal is to be found, which has been mentioned hitherto.

Towards Elm Lick and Rosine, from Beaver Dam, the beds ascend. The Elm Lick coal is brought to view, by the upward rise, at several places a short distance southwardly from Elm Lick, and also at Mr. Martin's coal bank, about one mile, or a little more, westwardly from the station, north of the railroad.

At Mr. Henry Thomson's coal opening, two miles south from Elm Lick, the coal is more than ordinarily thick. The following is a description of the bed at this place:

a.	Bluish drab argillaceous Shale		4½ feet.
b.	Coal, divided thus:		
b′.	Coal	17 inches.	6⅓ "
b″.	Clay, containing stigmaria rootlets	18 "	
b‴.	Coal	41 "	

The coal dips north 20° west, but at what rate could not be determined.

The bed is also exposed on land belonging to Mr. Julius Edward Otto, about one mile and a half southwest from Rosine. The upper member here measures twenty-one inches in thickness. Mr. Otto has drifted into the coal on his place, and it has been wrought in a limited way.

A short distance from Mr. Otto's drift, passing towards Rosine, but on the opposite side of the ridge, Mr. Robert E. Chiles has made entries in the coal at two places. Both entries were nearly filled with débris at the time these examinations were made. The thickness of the lower member of the coal could not be determined. The upper member measures twenty to twenty-one inches, and the clay parting seventeen and one fourth inches in thickness. Before reaching Rosine the coal seems to overshoot most, if not all, of the hill-tops. It is possible that it may be found in the knob just northeast of Rosine, the top of which is one hundred and thirty feet above the railroad at the station; but this is entirely conjectural.

Descending from Rosine towards Elm Lick, the beds dip rapidly in that direction, and the coal, which is wrought at Martin's bank, about half a mile northwardly from the Elm Lick water-tank, is brought down to a level, comparatively, forty or sixty feet above the railroad at the water tank.*

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*Of course this is not the height at which the coal would lie, were it present in the hill at the tank—the element of dip being yet to consider in the calculation.

At Martin's coal bank the bed measures as follows:

a′.	Coal	1 foot 6 inches.
a″.	Clay parting	6 "
a‴.	Coal	3 " 2 "
		5 " 2 "

The coal was measured where it had been freshly exposed, and may increase somewhat in thickness when followed under a better roof.

Journeying, in a somewhat northwestwardly direction, from Martin's bank towards Hartford, higher beds come to view. The fall of the beds is still rapidly towards the northwest. The Fusulina chert appears near the Morgantown road, about half a mile a little northeast of Dr. Berry's place, on the Morgantown road, and there it and the beds associated with it form the structure of the region on towards Hartford.

On Dr. W. J. Berry's land, about four miles from Hartford, the coal underlying the Fusulina chert crops out in a ravine draining towards the Morgantown road. The coal measures thus:

a′.	Coal dirt	7 inches.	19 inches.
a″.	Clay	6 "	
a‴.	Coal dirt	6 "	

The coal is underlaid by argillaceous shale, the upper part merging into an inferior sort of fire-clay immediately beneath the coal. Scattered fragments of the Fusulina chert are found on the hill-side above the coal.

The same coal is exposed in the road by Mr. Wm. Taylor's house, about two and a half miles from Hartford. But between Taylor's and Berry's there seems to be a considerable swell in the beds underlying the coal—a massive sandstone seeming to thicken, midway between the two places, at least twenty feet. This would be best explained by a cross section from Dr. Berry's to Mr. Taylor's. Just beyond Mr. Taylor's a higher coal crops out, near the forks of the road, which is equivalent to the one opened on Mr. L. D. Taylor's land, and also exposed on Rough creek, at the Hartford water-mill.

The following is the section from the forks of the road to Mr. Taylor's:

No.	Description of Strata.	Feet.	Inches.
1	Earthy, porous, yellowish Limestone, abounding in *Productus muricatus*	1	
2	*Coal* (No. 41 of general section)	1	
3	Space, about	8	
4	Fusulina chert, about.	. .	6
5	Space . . . . 10 to	15	
6	*Coal*	. . .	18

Proceeding northeastwardly from this place towards the Hines coal bank, the beds are seen to rise in that direction, as they mount the southwardly slope caused by the Rough creek uplift.

From Taylor's to the outcrop of Fusulina chert, on land belonging to the heirs of Richard Stephens, near the Morgantown road, about three miles from Hartford, the rise amounts to fifty feet; thence to the large spring on Hon. E. D. Walker's land (known as the "Nall's tract"), about two miles and three quarters north 70° east from Hartford, where the Fusulina chert is again exposed, the rise amounts to forty feet; and thence, to Hines' coal bank, the rise is fifty feet. Proceeding northwardly from Hines' bank, the coal wrought there, which is the equivalent of the Elm Lick bed, soon overshoots the tops of the lower hills.

At the Hines bank, which is about four miles south 80° east from Hartford, the Elm Lick coal has been wrought considerably. Two other openings in coal have also been made in the vicinity, but no mining done.

The following is the section of the beds in this vicinity:

No.	Description of Strata.	Feet.	Inches.
1	Fusulina chert	out	crop.
2	Space, not fully determined on account of dip in the beds. May be from . . . . 20 to	40	
3	*Coal*	. . .	26
4	Space, about	45	
5	*Coal*—the "working" bed—divided thus: *a.* Coal . . . . 1 foot. *b.* Clay . . . . 4 to 5 inches. *c.* Coal . . . . 2 feet 6 "	3	11
6	Sandstone, base not seen.		

This place is about two miles and three quarters, in a northwestwardly course, from the Martin coal bank, near Elm Lick.

Towards Hartford the beds sink and the Elm Lick coal disappears beneath the surface.

Two distinct coals make their appearance at Hartford, one at the water-mill and one in the left bank of Rough creek, just below the bridge over the stream, on the Owensboro' road. Apparently the coals lie near to each other in the series, but a computation of the dip shows the contrary to be true. From the Foreman grave-yard, where the limestone which overlies the lower coal is exposed, to the coal at the bridge, the dip is rapid. The condition of the beds can be well shown only by a cross-section, which may be given hereafter.

The following section exhibits the order of the beds about Hartford:

No.	Description of Strata.	Feet.	Inches.
1	Soft disintegrating Sandstone, top not seen	5	
2	Ochreous drab Shale	15	
3	Dark blue Shale	2	
4	Black bituminous Slate, containing fish scales	1	6
5	Coal	1	2
6	Under clay merging into shale below	6	
7	Grey shaly Sandstone and Shale	21	
8	Space, about	57	
9	Limestone (seen at the water-mill and at the Foreman grave-yard)*	6	
10	Shale, &c	10	
11	Coal	. . .	11
12	Under clay; very impure, base not seen	1	
13	Space†	8	
14	Fusulina chert	. . .	6
15	Space . . . 10 to	15	
16	Coal	1	6

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* Described in a following section.

† From No. 13 to No. 16 relates to the section by the Johnston house, at the forks of the Hartford and Beaver Dam and Morgantown road.

The limestone, No. 9 of the section, is well seen at the Foreman grave-yard, but the best exposure of it is in the bank of Rough creek, by the water-mill, just above Hartford. The following are the details of the section there:

No.	DESCRIPTION OF STRATA.	Feet.	Inches.
1	Drab argillo-arenaceous Shale; underlies a disintegrating Sandstone (top not seen).	5	
2	Bluish, earthy, shelly Limestone. In places somewhat concretionary in structure. Has an irregular fracture, and may be split into thin plates. Abounds in fossils, viz: *Spirifer cameratus*, *Chonetes mesoloba*, *Productus muricatus*, *Athyris* (*subtilita?*), *Productus Pratteniamus*, *Prod. Nebrascensis?* an *Aviculopecten*, etc.. . . . . . . ,	6	
3	Dark calcareous Shale; becomes quite calcareous at the base, and there merges into a coarse earthy lime rock. Contains fossils . .	8	
4	Tough, coarse-grained, dark lime rock	. . .	4
5	Very dark argillo-calcareous material, closely filled with *Productus muricatus*, and containing numbers of *Chonetes*.	2	
6	Black carbonaceous Shale, with "streaks" of coal traversing it . .	. . .	1½
7	Coal	. . .	11

At the Foreman grave-yard the limestone, No. 2 of the foregoing section, is seen, exhibiting its usual appearance in this district when removed from such constant action of moisture as that operating on it at the water-mill. It seems to be somewhat pyritiferous, and, in some places, is dark blue and hard, frequently with a soft crust. Usually, however, there seem to be two beds—the upper one being a bluish, earthy, shaly limestone, with occasional hard and more compact parts; the lower bed being a pyritiferous blue limestone in the interior, but with a very thick, soft, greenish and yellowish crust—the crust being filled with fossils. The two beds seem to merge into each other. The principal fossils of the shelly bed are, *Spirifer cameratus* (which are usually large) and *Productus Prattenianus*. The lower bed is filled with *Productus muricatus*. On the slope above the limestone ochreous concretions, containing unusually large specimens of *Productus muricatus*, were found.

The following is the section here:

No.	Description of Strata.	Feet.	Inches.
1	Covered space from hill-top	28	
2	Sandstone	3	
3	Covered space	7	
4	Sandstone	2	
5	Covered space	30	
6	Coarse bluish Limestone, breaking with a hackly fracture	1	
7	Covered space	1	
8	Coarse, earthy, greenish Limestone, containing many fragments of fossils, many of which seem to be remains of Crinoids; many fragments of *Spirifer cameratus* were also seen	1	6
9	Shelly blue Limestone, containing *Spirifer cameratus* and *Producti*	8	

The coal at the Hartford bridge has, by others, been referred to Coal D (No. 9 according to Dr. Owen's nomenclature); the sections that have been given are sufficient to show the error of this without going further into detail. It may be remarked, however, that Coal D is found in the Ben's Lick Hills, about two and a half miles below Hartford, and is shown by its topographical relations alone to be much higher than the Hartford coal; besides this, the Hartford coal sinks at a considerable rate in that direction.

It is possible, however, indeed it is probable, that one or more of the beds which are known to occur below Coal D, in the more southwardly part of the county, are absent in the region nearer Hartford, and towards the northwest. But it is also possible, that at least one bed which occurs in this region is not to be found far towards the south.

In the "Sugar Loaf" Hill, near Barrett's Ford across Muddy creek, about one mile southwardly from Hartford, two coals are exposed, the upper one being Coal E. A coal has also been opened in the bed of the creek at the ford. It is reported to be nearly three feet thick; but I was unable to verify this by personal observation.

The following is the section at the Sugar Loaf Hill:

No.	Description of Strata.	Feet.	Inches.
1	Slope	38	
2	Drab argillaceous Shale	5	
3	Black Slate	2	
4	Bluish-drab Clay	. . .	1
5	Coal E	1	5
6	Fire-clay (mostly)	5	
7	Greenish-drab argillaceous Shale	10	
8	Covered space	10	
9	Coal smut	. . .	10
10	Fire?-clay	. . .	6
11	Covered	45	
12	Sandy and argillaceous Shale	10	
13	Coal, reported. Is said to be covered with black slate. Thickness stated at	2	8

Westwardly from the conical hill Coal D is worked, at several places, in the Ben's Lick Hills. Coals E and E^a are also found there, the beds showing a sinking towards the northwest.

The following is the section at Brown's coal bank, where Coal D is worked:

No.	Description of Strata.	Feet.	Inches.
1	Slope from hill-top	10	
2	Sandstone	10	
3	Coal dirt.		
4	Limestone	3	
5	Covered space	51	
6	Argillaceous Shale	5	
7	Bituminous Slate	1	3
8	Coal D	4	
9	Covered space	89	
10	Coal covered by bituminous Slate. Coal measures	1	3
11	Covered space to Rough creek	4	

Down the creek, near the mouth of Brush creek, Coal E is exposed, nearly level with the bed of the creek, and higher up Coal D crops out, with the limestone (No. 4 of the foregoing section) exposed high up in the hill. The following is the section obtained in the locality:

No.	Description of Strata.	Feet.	Inches.
1	Covered slope from hill-top	40	
2	Limestone outcrop	1	
3	Covered space	49	
4	Sandy Shale in thick laminæ	2	
5	Blue argillaceous Shale	5	
6	Black Slate	1	
7	Coal D, partially concealed, probably	4	
8	Under clay, with limestone masses, sometimes as a bed, through it. About	5	
9	Thin-bedded shaly Sandstone, or Sandstone in thin laminæ	10	
10	Thinly-bedded sandy Shale	38	
11	Black, slabby, bituminous Slate	7	6
12	Bluish Clay Shale, with one half an inch of coal just above the bottom	...	7½
13	Coal, divided thus: *a.* Coal 7 inches. *b.* Clay 1 " *c.* Coal 1¼ "	...	9¼
14	Fire-clay, containing stigmaria rootlets	1	
15	Slope to Rough creek	4	

It must be said of this section, that it was measured, except where a foot rule could be applied, entirely with an aneroid barometer; accordingly, some of the distances between beds may not be given with absolute accuracy.

Coal D is also worked at Mr. Elijah Miller's coal bank, and is known to occur at other places in the locality.

On the northwardly side of Rough creek, at Mr. J. B. Bennett's place, on the Hartford and Livermore road, about three miles from Hartford, the coal bed, which underlies the Hartford limestone (seen at the water-mill there), crops out. The coal is thin; it is said to measure, when under a good roof, eighteen inches in thickness. A limestone, under which a coal dirt occurs, is found above the Hartford limestone at this place. It seems probable that it is local in its development. The following is the section here:

No.	Description of Strata.	Feet.	Inches.
1	Dark bluish-grey to dove-colored, rather compact Limestone; contains *Spirifer cameratus*, *Chonetes*, and small fragments of Crinoid columns . . . . 1 foot to	1	3
2	Space . . . . 0 to	. . .	6
3	Coal dirt . . . . 2 to	. . .	6
4	Chiefly argillaceous and sandy Shale	12	
5	Sandstone	5	
6	Space	3	
7	Blue shelly Limestone—the Hartford Limestone.	6	
8	Space	15	
9	Coal, reported to measure	. . .	15

Proceeding in a northeastwardly direction from Mr. Bennett's, the Hartford limestone is found at several localities towards Mr. Charles D. Stephens', on Rough creek, above Hartford. Several coals are found in the bluff facing the creek, at Mr. Stephens', and from their arrangement there seems to be here a distinct change in the character of the section from its appearance farther towards the south.

The following section exhibits the order of the beds here:

No.	Description of Strata.	Feet.	Inches.
1	Sandstone—massive	25	
2	Coal.	1	10
3	Massive Sandstone	40	
4	Space	5	
5	Coal.	2	2
6	Chiefly shaly Sandstone.	35	
7	Limestone; is probably not precisely in place, partially concealed.	2	
8	Coal, reported to be	2	
9	Space	5	
10	Chiefly Shale.	42	
11	Sandstone outcrop	3	
12	Covered space to the creek.	45	

Unusually thick coal is found in the region about Centertown and at Point Pleasant. So far, however, the identity of the bed has not been determined with certainty. It is believed best, therefore, to leave that question open for future solution.

At L. C. Morton's coal bank, about seven miles nearly due west from Hartford, the coal is reported to vary from eight to nine feet in thickness. It is divided by a clay seam varying from one half inch to one inch in thickness. The lower member varies in thickness from four feet four inches to four feet seven inches. The coal is of very good quality, as shown by the analysis given on a preceding page.

The same bed has been opened on land adjoining the Morton tract to the west, at Dooring's mine. Here the coal is more than eight feet thick, as shown by the following measurements made inside the bank:

a. Coal		3 feet	9 inches.	8 feet 4½ inches.
b. Clay	½ inch to		2 "	
c. Coal		4 "	5½ "	

Samples were also collected from this bank. At the time when these places were examined, the conditions were very unfavorable for obtaining accurate data upon which to base conclusions, and on this account it is deemed best to await further developments before endeavoring to identify the coal here with other known beds.

Below the coal there is a bed of iron ore of variable richness. It seems to underlie the coal on the Dooring tract and on the Morton tract, but its character is indefinite. At the Dooring mine eight feet of the ore was exposed, from which chippings for analysis were taken. According to Mr. W. C. Morton, the base of the bed was four feet lower than the bottom of the exposed portion. The analysis of the ore is given beyond.

What *seems* to be the westward extension of the Morton coal is wrought at Point Pleasant. The bed could not be well examined at the time the region was visited, as the bank was not in operation. But, from examinations made at the mouth of Mr. Patterson's drift, the bed seems to be eight and a half feet thick in places, taking into account two feet of poor coal towards the middle. The following section exhibits the arrangement of the beds at Point Pleasant:

No.	Description of Strata.	Feet.	Inches.
1	Sandstone	15	
2	Clay . . . . 2 to	. . .	4
3	Coal divided thus:		
	a. 4 feet good Coal . . . . *b.* 2 " poor " . . . . *c.* 2½ " good "	8	6
4	Covered space, chiefly Clay?	6	
5	Limestone; mottled drab and ash, and drab and ferruginous-red. In some parts contains *Martinia plano convexus*. . . 18 inches to	2	
6	Clay Shale	5	
7	Massive Sandstone extending to the Green river.	50	

The coal at Point Pleasant rises apparently between 5° and 10° north 40° east. The samples collected here for analysis were taken from the bed twenty yards in from the mouth of the entry, at Patterson's drift.

A number of coal openings, which were visited in the county, have not been described, as a discussion of them belongs properly in a detailed "County Report," which it is the intention to prepare hereafter.

Following are analyses of the most promising ores of iron found in the district covered by this report:

SAMPLES FROM DOORING'S ORE BANK.

	No. 1.	No. 2.
Iron peroxide	44.594	44.916
Alumina	20.419	13.204
Lime carbonate	trace.	trace.
Magnesia	.248	.176
Phosphoric acid	.287	.280
Silicious residue	26.550	32.504
Water	8.860	8.920
Total	100.958	100.000
Metallic iron	31.216	31.241
Silica	23.420	24.46
Phosphorus	.125	.177

ASHBY'S ORE.

Iron peroxide	61.179	Metallic iron	42.825
Alumina	15.503		
Lime carbonate	trace.		
Magnesia	.176		
Phosphoric acid	.648	Phosphorus	.283
Silicious residue	13.830	Silica	9.96
Water	9.273		
Total	100.609		

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, Director.

REPORT ON

THE LIMONITE ORES

OF

TRIGG, LYON AND CALDWELL COUNTIES,

KNOWN AS THE

"CUMBERLAND RIVER ORES."

BY WM. B. CALDWELL, Jr.

STEREOTYPED FOR THE SURVEY BY MAJOR, JOHNSTON & BARRETT, YEOMAN PRESS, FRANKFORT, KY.

INTRODUCTORY LETTER.

Professor N. S. Shaler, *Director Kentucky Geological Survey:*

Dear Sir: The following report is a continuation of the former paper on Western Kentucky, and will close, for the present, work in that region. The next report will be on the Eastern Kentucky district—the coals and iron ores. In making the following report, I have dwelt upon the question of steel, because ores suitable for the manufacture of even common grades of steel are so rare in the United States, and especially south of the Ohio river. This renders an ore, which can be used, far more valuable than its percentage of metallic iron would indicate.

WM. B. CALDWELL, Jr.

THE LIMONITE ORES OF TRIGG, LYON, AND CALDWELL COUNTIES, KNOWN AS THE "CUMBERLAND RIVER ORES."

These ores were mentioned in my general report on "Ores and Coals of Western Kentucky," a paper submitted in February, 1878. Since then, my time has been devoted to the chemistry and metallurgy of steel-making; and, with the opportunity of thoroughly investigating the use of brown ores for the purpose, I have been more than ever impressed with the importance to the State, and more especially to Western Kentucky and Louisville, of the ores of which this paper will treat. The region has already gained a reputation for excellent iron, particularly for boiler plate, and "Cumberland River Iron Works" and "Hillman's Boiler Iron" are well known; but the advantages of the district are not known. If so favored a region lay in Ohio, Pennsylvania, or any State north or east, great developments would have been made long ago, and many thousand tons of iron would be annually brought over the Elizabethtown and Paducah Road to Louisville.

This report is intended, as all the Survey reports are, to bring to public notice the undeveloped wealth of the State; but in this paper it is intended, especially, to call attention to the fact that, only one hundred and seventy-five miles from Louisville, are extensive deposits of an ore suitable for making steel, a fact which is undeniable, and that the iron made from it could be put down at Louisville at a less cost than such iron sells at Pittsburgh or elsewhere.

In order the more efficiently to show the character of the ore, quality of iron produced, etc., Trigg and Centre Furnaces will be discussed at some length; for here we have practical proof of the working of the ore, and of the excellent quality of pig and wrought iron made; but first, a general description of the district: The Tennessee and Cumberland rivers enter Kentucky only a few miles apart, and cross the State side by side to the Ohio. Between the rivers, and on the eastern bank of the Cumberland, from Tennessee down to Livingston county, just beyond the crossing of the Elizabethtown and Paducah Road, about thirty miles in length, lies the iron ore deposit.

The coal measures extend southward into Caldwell county, about five miles from Princeton, where there is a deposit of the ore; and on Caney creek, about fifteen miles from Princeton, several five-foot veins of excellent coal have been opened.

It would be useless here to do more than mention the fact that the coals of Western Kentucky are suitable for iron-making, and can be mined very cheaply; for they were fully discussed in the former paper, with numerous analyses of coal and coke, and figures showing cost of mining.

The ores are in great abundance on the river banks and on the railroad. At and near Kuttawa, the crossing of the Cumberland, on the property of Governor Charles Anderson, are several extensive beds or pockets of ore, which were once mined largely for a charcoal furnace run there by Mr. Kelly, now of Louisville.

The railroad cuts through a heavy deposit, and there are mines at distances varying from one half to three miles. These deposits are a fair average of the occurrence in the whole region. The ore seems to have been deposited in the form of "pot ore" and "kidney," and at some points as "pipe ore," in a clay and chert formation, but subsequently subjected to disturbances which have mixed the broken pots, etc., more or less intimately with the clay and chert. Whether this was the manner of formation or not, and what the nature of the disturbances was, whether simply upheavals or the natural disintegration from washing down of the strata, is of no moment here. The appearance of the beds indicates such a process, and this describes sufficiently well, to any one who has not seen them, the nature of the deposits; but, I must add, that the masses of ore, uncontaminated with clay or chert, are often very large, weighing sometimes tons, and that the smaller lumps may be easily taken out free. The only drawback is, that a certain quantity of dead work must be done in removing the clay and chert. This, however, is not at all expensive.

As to the amount of ore in a bed or pocket, it would be impossible to calculate, as none of them have ever been exhausted; the part above ground being apparently all ore and clay, and the ore seeming to run down the surface to a considerable depth.

The extent to which this commingling of ore and chert has been carried on varies considerably in different deposits, and also in the same deposit; but the ore, when carefully mined, as it is for use, varies very little in composition, as several analyses in my previous paper, and further analyses below, will prove. Ascending the river, deposits of ore are found here and there along the river and railroad. Above Eddyville, a station on the river and railroad, there have been several charcoal furnaces—Monmouth, Fulton, etc., and lately Centre and Trigg.

The old furnaces made iron when there was but little communication with distant points, and ten tons a day was a very large yield, but it was cold-blast charcoal iron. It was common then to make large sugar-kettles, iron pots, and common castings by running the iron from the furnace directly into the moulds, and it was a profitable business.

In these days of hot-blast coke furnaces, making sixty tons, and even much more, a day, the iron business on a small scale scarcely pays; and the combination of practical with theoretical knowledge of furnaces and the working of metals has brought the industry so far forward that production exceeds consumption, although many new uses are found for iron every day. On account of this over-production the industry has suffered severely during the past five years, and only highly favored localities can succeed—localities combining the following advantages: Abundant supply of good cheap coal near cheap ore, limestone, and water, and with transportation facilities to a near and good market. Or for charcoal iron, which always brings a higher price for certain purposes, good cheap ore must lie in a well timbered country, with plenty of limestone and water, with the same requisite transportation facilities. Such localities exist in Western Kentucky for coke iron and for charcoal iron.

CHARCOAL IRON.

The furnaces referred to above—Centre and Trigg—will afford evidence of the adaptability for charcoal iron, excepting that transportation is not as cheap as it might be.

About ten miles above Eddyville are the boiler-plate works of D. Hillman & Sons, for which the furnaces in question were run, and which I will describe briefly after speaking of the furnaces.

TRIGG FURNACE.

This furnance is on the eastern bank of the Cumberland, about three miles inland, and five miles above the rolling mill just mentioned. It has been out of blast for some time, but is well kept, and in good condition.

The stack is large and well shaped, has closed top and down-take pipes for the gases, which are utilized for heating the blast. The hot-blast ovens are arranged so that they can be fired with fuel or with waste gases, or both. There is a good steam hoist for raising ore and fuel to the tunnel-head. Three horizontal blowing engines furnish blast, and these are well preserved. Altogether, the plant is in good condition, and would require but little work and repairing to start up again. The ore banks about the furnace are very extensive, and are only about one mile distant, the ore being brought by cars down grade on a narrow gauge tramway, and empty cars hauled back by mules. This ore is of the same general character as that in the other parts of the region, occurring in great beds, and more or less mixed with chert and clay. It requires very little mining, only being at all expensive on account of the dead work in removing clay and chert. Immense pits have been dug, leaving a bottom of ore, which extends to a considerable depth below the general level, and these pits continued into the hill. The drawback to this method of mining is the water which accumulates, and for that reason it would, in the end, probably be economical to tunnel or drift into the hill, and then work passages off to the sides, and also to work down.

Mining it, however, as it was done, was very cheap, not costing over $1 10 to put the ore down at the furnace, and to keep it very clean and free from chert. This was the easier from the fact that the lumps of ore are individually quite free from impurity, and are often of great weight, so that when gotten out and broken up they need no further cleaning. As to quality, the ore is very similar to that already mentioned. On page 8 of the former report are several analyses of limonite ores from the district, and the following show the similarity, as also the excellent character of the ore.

1. Ore taken from bank worked for Trigg Furnace.

2. Ore taken from bank near by, which had also been worked.

	1.	2.
Iron oxide	70.31	69.93
Alumina	2.54	3.12
Lime	1.89	1.53
Magnesia	1.48	1.62
Water	10.70	10.21
Silica	12.91	13.45
Total	99.83	99.86
Metallic iron	49.210	48.950
Phosphorus	0.091	0.087

Limestone is abundant and good; and, being at hand, could not cost more than seventy-five cents per ton.

Good charcoal timber surrounds the furnace and ore banks, and, although the furnace has been worked for some years, the timber is not thinned out. I was told in the country there that contracts could readily be made to furnish charcoal at four and a half cents per bushel; but, putting it at five and a half cents a bushel, the fuel for a ton of iron would not cost over seven dollars. Labor is abundant and cheap, the native population being glad to get work; and then there are many negroes, already trained to the work, who make excellent furnace hands. Water is plentiful and constant from a large spring and creek.

With the raw material at the furnace for the figures above stated, the cost of making iron would be about $14 25 per ton, and should not be more, as the estimates are full.

Charcoal, per ton of iron	$7 00
Ore, two and one fourth tons	2 50
Limestone, two thirds ton	50
Labor and incidentals	3 00
	$13 00
Add ten per cent. for any loss	1 30
	$14 30
Add two dollars, freight to Louisville	2 00
Total	$16 30

And we have a warm-blast charcoal iron of the best quality—equal in all respects to irons selling at Louisville now for twenty-three dollars, No. 1, and eighteen dollars "Mill" grades. Supposing the furnace to make half of No. 1 and half "Mill," the average would be twenty dollars and a half, which would leave a handsome profit.

The iron would have about the following composition, this being an analysis of Trigg iron:

Iron	94.71	per cent.
Carbon	2.87	"
Silicon	1.93	"
Phosphorus	0.18	"
Sulphur	trace.	

CENTRE FURNACE.

Returning to the rolling mill, and crossing the Cumberland, we find Centre Furnace, two miles off to the west, in Lyon county. The site of the old Fulton Furnace is near by.

Centre is also a large charcoal furnace, with modern improvements — a large stack, in good condition, good outbuildings, steam hoist, horizontal blowing engines, etc. The surrounding hills are full of ore, and several mines have been worked quite close to the furnace.

The ore is of the same general character as that in Trigg and Caldwell counties, is mined in the same way, just as cheaply, and yields as well in the furnace. Analysis shows it to be as pure, the following being an average sample taken from one of the mines:

Iron oxide	71.13
Alumina	2.29
Lime	2.61
Magnesia	1.48
Water	10.89
Silica	11.26
Total	99.66
Metallic iron	49.80
Phosphorus	0.092

This furnace is also surrounded by good charcoal timber; water is abundant, and limestone of good quality quite near. The cost of making iron would then be about the same as at Trigg Furnace.

The iron from these furnaces has been used to make the boiler-plate so well known on the steamboats in our Western rivers, and which has gained so general a reputation for excellent quality and uniformity. The process, however, is the most expensive used in iron working, and hence the mill has not kept in full blast during the past year or so. The pig iron is treated in small charcoal knobbling fires—that is, it is made into wrought iron by puddling in charcoal. The charcoal blooms or balls are shingled, rough rolled, cut and piled, then heated and rolled. The bars are cut and piled for plates, heated and rolled to plates of different sizes and thickness. The rolling mill is quite extensive, consisting of large rolling mill building, out-houses, machine shops, etc., knobbling furnaces or fires, refinery, hammers, shears, etc.

The plate trains are, for large plate 26-inch, and for small plate 18-inch, well arranged and adapted for the work. By the process of "knobbling or sinking" the 0.18 per cent. of phosphorus is reduced to 0.03 per cent., which, to a great extent, accounts for the excellence of the plate, and its great strength. Having shown what the ore is capable of in making charcoal iron and wrought iron from it, I will refer to the question of making a cheap iron suitable for steel, using coke as fuel in the blast furnace.

COKE IRON.

The fact has already been mentioned that the coal field of Western Kentucky extends to within a very few miles of these ores, and that the coal, which is of excellent quality for iron smelting, occurs in veins five feet in thickness.

The E. & P. Road cuts through this coal field, and already the line of the road is dotted with numerous coal mines, which furnish coal to Louisville at a price lower than Pittsburgh can send it. Coke ovens have already been erected, and the coke has a good reputation with iron men.

Along this road are many points which would be excellent furnace sites. There is Rockport, where the road crosses the Green, a river navigable at all seasons, and Nortonville, the crossing of the E. & P. and St. Louis and S. E., and many other places in the coal field; or, if one preferred taking coal to the ore, there are favorable locations in the ore region. Either way the distance need not exceed thirty or forty miles, and could be put at much less.

Coal can be mined very cheaply, and two tons coke should not cost over $2 75 at the mines; if freight for thirty miles were added, it would not be over $3 50. The ore can be mined for one dollar—say $2 50 for two and one fourth tons—freight on two and one fourth tons thirty miles would make it, with the loading and unloading, about $3 50. Then the cost per ton of iron would be—

	At the coal.	At the ore.
Coke, two tons	$2 75	$3 50
Ore, two and one fourth tons	3 50	2 50
Limestone, three fourths ton	60	60
Labor and incidentals	3 00	3 00
Total cost	$9 85	$9 60
Freight to Louisville	1 50	1 75
	$11 35	$11 35
Add ten per cent. on total cost	96	98
Cost at Louisville	$12 31	$12 33

These estimates are for a grade of iron from which steel for rails or merchant bar or "shapes" could be made at a low figure. Any concern which could buy such iron at Louisville for sixteen dollars would not need to fear failure in steel-making.

GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, Director.

A REPORT OF A RECONNOISSANCE

OF A PART OF THE

BRECKINRIDGE CANNEL COAL DISTRICT,

BY CHARLES J. NORWOOD.

STEREOTYPED FOR THE SURVEY BY MAJOR, JOHNSTON & BARRETT, YEOMAN PRESS, FRANKFORT, KY.

INTRODUCTORY LETTER.

Professor N. S. SHALER, *Director Kentucky Geological Survey*:

DEAR SIR: In accordance with your instructions, I herewith present a report of a reconnoissance, made in 1875, on that part of the "Breckinridge Cannel Coal" district (lying partly in Breckinridge county and partly in Hancock county) which is known as the property of the "Cloverport Coal and Oil Company."

This report is largely a rearrangement of one made, by your direction, to Col. J. C. Johnston, of Louisville, Kentucky. As that report was partly written in the field, however, and within a limited time, some of the facts were not so carefully weighed as otherwise would have been done. A more careful study of my notes has shown the necessity of modifying some parts of that report, and some new matter has been added, so that, although largely a rearrangement of the one furnished Col. Johnston for his immediate information, this report may be regarded as more accurate and complete. The changes made, however, are comparatively few, and, under the circumstances, do not materially alter the value of the former estimates. Some new computations (based on a more recent determination of the specific gravity of the coal) have been made for the estimated amount in tons of the coal underlying the lands. This, to a certain degree, affects the estimate for the possible total income which may be derived from the property; but the effect would be apparent only in the future.

The work of computing the probable income which may be derived from mineral lands is always subject to revision, and, as in the present instance, serves rather for illustration than as a strict mathematical fact.

The yearly income is necessarily dependent on the price that the coal will fetch in the various markets. These prices fluctuate, and, as a consequence, an estimate made now for the probable income, using the present market value of the coal as a basis for computation, would be subject to revision at any time.

This, however, does not alter the value of the estimates for the use of those having experience in such matters.

The estimate for the cost of mining, etc., is subject to little change on account of fluctuations, and remains as given when the report was originally prepared.

Respectfully,

C. J. NORWOOD.

REPORT OF A RECONNOISSANCE OF A PART OF THE BRECKINRIDGE CANNEL COAL DISTRICT.

I.

DESCRIPTION OF THE PROPERTY, ETC.

According to the data furnished me, it appears that the various boundaries of the property of the Cloverport Coal and Oil Company inclose about 7,224 acres, lying southwardly from Cloverport, as represented in the following statement:*

In fee-simple	4,744	acres.
Mineral rights in perpetuity	1,970	"
Cloverport town and river property, on which stand the old factories and accessory buildings, the Superintendent's cottage, and "Cairn's Castle,"	60	"
The "Crawford" farm	436	"
A lot on the railroad	2	"
Railroad rights of way	12	"
Total	7,224	"

"The 'Crawford' farm is detached, lying about one mile and a half east of the principal body of the estate, which includes about 6,500 acres."

The especial value of the section examined lies in the deposit of cannel coal which is found on it. Several "entries" were driven by the "Breckinridge Cannel Coal Company," a number of years ago, for working the coal.† If the report is correct, these mines were at one time operated by their former owners solely for the manufacture of illuminating oil from the coal.

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*Cloverport is on the Ohio river, 260 miles below Cincinnati. It is 110 miles below Louisville, 190 miles above Cairo (which is at the junction of the Mississippi and Ohio rivers), and 1,182 miles above New Orleans.

†The amount of coal removed by that company was, so far as can be learned, comparatively little. A report has been circulated somewhat to the effect that the deposit has been practically exhausted; but I have been unable to verify it in any way. There is in Col. J. C. Johnston's possession a map, said to be authentic, exhibiting the area of coal removed up to the time that the mining was suspended. Their condition was such that the old entries could not be surveyed when I visited them.

From a report of the directors, issued in pamphlet form, it is learned that the erection of the oil works was commenced by the Breckinridge Coal and Oil Company in the autumn of 1855, and that in April, of the following year, twelve retorts were in operation, producing from 600 to 700 gallons of crude oil daily. In June, 1856, that company and the "Breckinridge Cannel Coal Company" consolidated; following which, an extension of the works was undertaken, and, in the succeeding year, eighteen additional retorts were put in place.

All of the apparatus about the works was the best of its kind; and, had not the discovery of natural oils been made, there is little reason to doubt that a prosperous business would have followed.

Disastrous fires, the discovery of petroleum, and the commencement of the war between the States, all happening near together, however, caused the abandonment of the works till now, when, if the matter is correctly understood, it is desired to establish a colliery at the old mines, and mine the coal for general exportation.

Some knowledge of the extent of the cannel coal bed, incidentally taking into consideration the general worth of the property, and the estimated cost of placing the mines in working order once more, was accordingly desired.

Having a pressure of work in another direction, the time that could be given to this matter was limited, and was not sufficient for me to enter into such detailed explorations as would be desired for the preparation of a complete statement. So far as they were extended, however, the observations were such as would impress the observer with a high sense of the worth of the lands.

The surface of the region is naturally varied, according to the character of the underlying beds. Towards the Ohio river a sandstone is usually the first bed below the surface, and, as a consequence, there is a considerable proportion of comparatively flat or undulating surface in that direction; the same conditions are also found along some of the streams in the interior. The larger part of the property, however, is hilly, the hills frequently rising rather sharply from the lowlands.

The tops of the hills are frequently "rolling," and furnish a few admirable localities for farms. A large proportion of the land, however—especially where, in the immediate vicinity of streams, the shale beds of the Sub-carboniferous Group are the first ones below the surface—is too broken to be desirable for farming purposes.

The most prominent feature in the geography of the region is a long, irregularly trending ridge, which passes southwardly through the property. It is said to vary from one quarter of a mile to two miles in width.

This ridge forms the water-shed for the region near it, and has a distinct value, not only topographically but geologically, as within its structure the bed of cannel coal is contained. Accordingly, to know the true form of the ridge becomes very necessary in order to determine with accuracy the extent of any of the beds contained within it. Until this shall be done, all work in that direction is, of necessity, estimative.

II.

AGRICULTURE.

The agricultural aspects of the property are fair, certain portions of the land being fairly well adapted for the growth of small grain, while some parts serve admirably for the production of tobacco. It may be said that, as a whole, this region will compare favorably with the general class of lands, with like geological conditions, in the southwestern portion of the State, for the growth of corn and tobacco—the staple products of Western Kentucky.

There are two sorts of soil to be distinguished within the limits of this property: that on the hills has, usually, a sandy composition, while that in the lowlands is, in a large measure, calcareous.

Although it is somewhat in advance of the regular order of the report, it seems proper at this place to call attention to the green and reddish marly shales, which are found on certain parts of the estate or in the vicinity, overlying the great sandstone which occurs first above the massive limestone of the Sub-carboniferous series. These shales or marls are valuable, and are worthy of much consideration, as they bid fair to prove most admirable fertilizers for some of our impoverished tobacco lands. Their geological position is in the Chester Group, and they are found, wherever it is well developed, over a large portion of the western part of the State. They are undoubtedly destined to become quite valuable to Kentucky farmers, especially to tobacco-growers; and it is possible that they may form the basis for a large manufacturing interest.

The marls are wonderfully rich in *potash* and *soda*, and for that reason they possess properties which, when their proper treatment shall be determined upon, should render them unexcelled for fertilizing worn-out tobacco lands. Tobacco extracts proportionately more potash than any other material from the soil; so that, in order to restore its former vigor to the soil, it becomes necessary to supply it with the substance in one of two ways: either with the potash in an uncombined condition, or with some mixture holding a large proportion of that material.

These marls may be used with benefit by simply spreading them thinly over the surface in the form that they are found in the bank, allowing the coating to remain on the ground throughout a winter, and then turning it in with the soil in the spring. It has also been suggested that they may be roasted in a kiln with lime. The advantage to be derived from such treatment would lie in the increased amount of potash, etc., that might then be taken from the mixture, within a certain time, by the simple atmospheric agencies, and mingled with the earth.*

Especial attention has been directed to these marls by Prof. Shaler and the chemists of the Survey. Should the experiments undertaken by Mr. Talbutt, for the purpose of testing the practicability of making the marl an article of commerce, prove successful, this point would be a desirable one from which to make shipments, being, as it is, within easy reach of water transportation. The marl beds are not distant more than two miles from the Ohio river, and may be found even nearer. At "Buffalo Lick," which, however, is not on this property, the marls are especially thick.

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* For further discussion of the question, see the biennial report of the Director of the Survey.

These marls are wonderfully alike in their composition, so far as yet known, wherever they are found in Western Kentucky. Unfortunately a sample of the marl in this region, although collected, was lost; but the following analysis, made by the chemists of the Survey, of a sample collected from Haycraft's Lick, Grayson county, will serve to show what may be expected from the marl in this region:*

COMPOSITION, DRIED AT 212° FAHRENHEIT.†

Alumina, iron, etc., oxides	27.811
Lime carbonate	.880
Magnesia	.824
Phosphoric acid	.109
Potash	5·554
Soda	.657
Water and loss	4·245
Silica and insoluble silicates	59·920
Total	100.000

According to the statement made by Captain William H. Pitts, there are already fifteen or twenty farms on the property of the company, each farm being provided with dwelling-houses and the necessary farm-yard buildings. The number of acres under cultivation was not learned.

TIMBER.

The larger portion of the property (that not under cultivation), is covered with a healthy growth of timber, including white oak, black oak, red oak, pin oak, and chestnut oak, poplar, ash, elm, sugar-tree, maple, linn, cherry, sweet gum, etc.

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* Samples of the marl were placed on exhibition in the Kentucky Department of the International Exhibition at Philadelphia.

† The partial results of Mr. Talbutt's investigations have been made public through the columns of the *Kentucky Yeoman*, Frankfort, Kentucky.

This forest supply is an item of much importance, and should be duly regarded, as our forests of oaks (especially of the white and chestnut varieties) are yearly becoming more valuable. Considering the demand there is for timber at Evansville, Indiana, and at other points on the Ohio river, it seems remarkable that so little has been removed from this section.

III.

THE COAL, ETC.

As previously stated, the chief value of the property is derived from the bed of cannel coal which underlies certain parts of it. The cannel bed is not the only coal found on it, however; on the contrary, there is certainly one distinct bed of bituminous coal above the cannel bed—possibly more. There seem to be possibilities, also, that an iron ore of good quality is to be obtained on the land, or within a short distance of its limits. In examining a collection made by Major Atkinson, said to have been collected entirely on this property, samples of very admirable limonite, similar to the Subcarboniferous limonite worked in Trigg county, this State, were observed. No evidence, however, more trustworthy than this was obtained indicating the existence of any valuable ore deposits on the estate. It is not at all improbable that the specimen in Major Atkinson's collection was obtained in the ore region bordering the Cumberland river, and was present in the collection by a mistake.*

As originally written, an attempt was made in this report to give an approximate section of the more important beds in the ridge which forms the central point of interest in the region. Subsequent considerations, however, have rendered it inexpedient to make the attempt a matter of record; accordingly, the following statement is an approximate section of only those beds underlying, and including, the cannel coal:

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*Since this report was written, this region has been examined by Mr. P. N. Moore—having come within the limits of his survey of the section along the eastern face of the coal field. It has accordingly been more thoroughly studied by him than by me; and the questions concerning the existence of ores in the region; of the form, height, and extent of the ridge, which has been mentioned on a preceding page, and the details of the structure of the ridge, are properly ones to be treated of in his report. It is to be hoped, also, that Mr. Moore's examinations, being more final in their nature than were mine, may have served to determine with accuracy the general character of the cannel bed; whether it preserves its condition as a cannel throughout its extent in this region, or merges into bituminous coal at some point beyond that reached by those openings that have been made in it at the mines; it may also have been possible for him to determine more definitely the extent of the bed, and hence the acreage of the coal. (April, 1877.)

1.	Cannel Coal	22 inches to 3 feet 2 inches.
2.	Sandstone and Shale, about	40 "
3.	Limestone and Shales ("Chester" beds), about	110 "
4.	Massive Sandstone (base of Chester Group), about	60 "
5.	Massive Limestone (St. Louis Group).	

For want of an accurate map, it is impossible to locate the various coal outcrops.* Bituminous coal has been found at several localities on the estate. At present, however, the bituminous coal has little commercial value; but seems to serve more especially to indicate the probable presence of the cannel bed.

It is probable that no cannel, the "Boghead" of Scotland (which, in fact, is not a true cannel) excepted, has received more general attention than that which has been bestowed on the bed found in this region; its remarkable general character and its quality as a gas enricher have already been discussed in some detail in former geological reports on Kentucky, and in kindred works.

The coal is remarkably dense in structure and tenacious; vigorously resisting cross-fracture, although cleaving with tolerable facility in the direction of the laminæ. Its character is such, in fact, that the coal stands handling and weathering more than ordinarily well, sustaining thereby little loss in bulk either in mining or transportation.

In Gesner's work on coal oils† attention is drawn to the curious fact that, although analysis proves the Boghead cannel to have the largest per centage of volatile matters, the coal actually produces *less oil* than does the Breckinridge article.

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*A map, prepared by a gentleman who had formerly examined these lands, was furnished me when in the region, and an attempt was made to use it when this report was originally prepared Its imperfections are so apparent, however, that it has proved to be of little service. A correct map of the region has been made by Mr. Wm. Byrd Page, Topographical Assistant to the State Survey, in the course of the later investigations in the section, and may be issued at an early date. (April, 1877.)

†New York: Bailliere Brothers, 1865.

The following is a comparison made by Gesner of the two coals: The Boghead cannel yields 120 gallons of crude oil to the ton, from which are obtained 65 gallons of illuminating oil, 7 gallons of paraffin oil, 12 pounds of paraffin—equal to about 84 gallons of marketable oils.

The Breckinridge coal yields 130 gallons of crude oil to the ton, from which are obtained 80 gallons of illuminating oil and 12 gallons of paraffin oil—making 92 gallons of marketable oils. Other products, such as aniline, benzole, etc., not uncommon to coals, are to be obtained from the cannel.

The extraordinary value of the coal for the manufacture of illuminating oil may be appreciated, when the fact is remembered that a coal which will yield 60 gallons of crude oil, or 40 gallons of refined oil to the ton, is regarded as an excellent article.

In fact, excepting the natural reservoirs of petroleum, the Breckinridge cannel undoubtedly offers one of the most productive sources yet known for the distillation of illuminating oils, and should it be necessary in the future to again manufacture our oil from coal, this article will be of very great value.

For the present, however, the especial and decided value of the coal depends upon its quality as a steam fuel and gas producer. This value is fairly indicated by the following analyses:*

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*The differences between the analyses are probably, in a large degree, due to a difference in the samplings. The quality of any coal bed is variable according to the conditions existing in its various parts; to equalize this, by making an average of its quality as found at different parts of the bed, should be the aim of the one who takes the samples; this is very difficult to do in the case of cannel coal. Everything considered, the analyses do not compare unfavorably with each other.

COMPOSITION.	No. 1.	No. 2.	No. 3.
Moisture	1.30	1.44	.64
Volatile combustible matter	54.40	62.40	61.30
Fixed carbon	32.00	28.20	30.00
Ash	12.30	7.96	8.05
Total	100.00	100.00	99.99
Specific gravity	1.318	1.339	. . . . .
Analyst	Peter.	Owen.	Gesner.

The amount of sulphur in Nos. 1 and 2 was undetermined; in No. 3 there was a trace.

These analyses (at least Nos. 1 and 2) were made quite a number of years ago; and the probabilities are, that in no case was an attempt made to procure fairly *averaged* samples of the coal—as was the case with the larger part of the tests made in those days to ascertain the quality of coals. The analyses were probably made from specimens which were collected without due regard being had for possible changes in the character of the bed at different places.

It is probable that, of the three analyses, No. 2 may be considered as the best fitted for general application. It is an average of *four* analyses made by Dr. D. D. Owen, and published in one of the volumes of his geological reports on Kentucky. Dr. Robert Peter mentions, in the report from which analysis No. 1 is taken, that the per centage of sulphur obtained in one air-dried sample of the coal was 2.433. This, however, is undoubtedly too high a per centage for the average amount of sulphur in the coal.

When this report was first written, the only available analyses of this coal (within my knowledge) were those which have been presented. Since then, however, an analysis, made by the chemists of the Survey, of a sample collected by myself, has been obtained. It is here presented, with the belief that it will be found to be a fairer indication of the *general* quality of the coal than any of those analyses previously given;*

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* For the purpose of comparison, a set of analyses of other cannels is appended to this report.

Specific gravity	1.213		
Moisture		1.30	
Volatile combustible matter		59.60	
Fixed carbon		27.00	Coke 39.10.
Ash		12.10	
Total		100.00	
Sulphur, two determinations	1.890 and 1.903		

The quality of the coal as a gas *producer* is fully indicated by the above analysis, although the value of the gas, measured by its candle power, is yet to be determined. The fact of its great value as a producer of gas has also been proved by a practical test—considerable quantities of the coal having been at one time shipped to New York, and sold there at the rate of $15 and upwards the ton for enriching gas. It is in view to have photometric tests made of the gas produced from the coal, which, it is believed, will prove satisfactory.

IV.

THE EXTENT AND TONNAGE OF THE COAL.

An essentially important point to be determined in the inquiry concerning this coal is its acreage. The importance of a good map, showing the details of the topographical features of the lands, was very apparent when the reconnoissance was made. With the assistance of such a one as should be prepared, it would have been comparatively easy, it is believed, to lay down the area of the bed with some accuracy; but without it, especially since the examinations were not so thorough as would be desirable, all computations as to the acreage of the coal are necessarily *estimative*, and are to be regarded only as such.

From the testimony of others and from personal observations, it is believed that about 4,000 acres may be roughly assumed as the number which are, in all probability, underlaid by the coal; which would include an area of about six square miles.* In making this estimate the "Crawford" farm and

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*It is very important for it to be understood that this estimate is based on the condition that the deposit is a true bed, and but little more subject to abrupt changes than is usually the case with coal beds. That this is true for the bed, *as a bed*, there is little doubt, at least so far as concerns this area; but the question concerning its constancy as a bed of cannel, whether at some places it may or may not merge into bituminous coal, is not considered. It must be borne in mind that the work was preliminary, and that the results are to be considered as preliminary to other work, hence on this point (especially), and kindred ones, the writer does not feel prepared to give his opinion unqualifiedly.

the "town property" (a total of 496 acres) are excluded; no coal will be found on the latter land, and very little is known concerning the former.

Whether this coal is to be found beyond the limits of this property is a question of much interest in the neighborhood. At present, any views in that connection must necessarily be based entirely on conjecture.* It may be well to quote, however, from the impressions recorded when this report was originally outlined: "Although unprepared with any absolute data concerning the question, the opinion that it may be found towards the southwest and west for a limited distance, provided the geographical conditions are favorable, may not be altogether improbable. There is undoubtedly a considerable gap in the extent of the bed beyond the boundaries of this property, and the quality of the coal may deteriorate—the bed may merge into bituminous coal. It is not probable that its quality will improve. The cannel does not seem to extend very far in any direction beyond the boundaries of the particular section under consideration, as the coal found elsewhere, which is thought to occupy the same relative position as the cannel bed in this district, is of the 'bituminous' kind."†

The thickness of the coal varies from twenty-two inches to thirty-eight inches, and the bed is reported to have occasionally measured forty-four inches in thickness. It is, therefore, a difficult matter to accurately determine the number of tons of coal to the acre. It is stated by trustworthy men, that the thickness of the bed is oftener three feet than two feet; it seems more prudent, however, to underrate than to overestimate the tonnage; accordingly, the average of the measurements (two and a half feet) is used as the basis for calculation.

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*The truth of this was particularly impressed upon me by a journey made from Cloverport to Hawesville in the spring of 1876. At this time it seems extremely improbable that the bed, as a cannel coal, extends much beyond the west limits of the Cloverport Coal and Oil Company's property. (April, 1877.)

†For more specific information on this point, the reader is referred to Mr. Moore's forthcoming report on this region. The more accurate results obtained by him in his study of the district may have been sufficient to determine the full extent of the bed, and to solve the questions concerning its general character. (April, 1877.)

With a specific gravity of 1.213, which is the specific gravity indicated by the analysis of the samples analyzed by the chemists of the present Survey (see page 14), a thickness of 2½ feet would produce 3,685.7 tons to the acre, or 14,742,800 tons for the 4,000 acres (using the ton of 2,240 pounds), should that area prove to be underlaid by the cannel. Assuming a smaller acreage for the coal, however—for instance 3,250 acres—the result would be 14,374,230 tons, measuring the thickness of the bed at 3 feet; which, under the circumstances, would seem allowable. According to this computation, the coal would last for 287 years, with an annual output of 50,000 tons.*

V.

THE COST OF PRODUCTION.

The present price paid for mining is one ($1) dollar the ton *to the miner*. To this may be added seventy-five cents the ton to cover all additional expense incurred in removing the coal from the mine and placing it on barges on the Ohio river at Cloverport.

The towage to New Orleans, so I am informed by coal-shippers, may be placed with safety at not more than seventy-five cents the ton. Should the mine-owners have their own barges and tugs, however, the freightage would be less.

The total cost per ton of the coal, when arrived at New Orleans, may then be represented thus:

Amount paid for mining	$1 00
Amount paid for removing from mine and placing on barges	75
Towage to New Orleans	75
Assumed amount to cover all incidental expenses—insurance, etc.	50
Total cost, delivered at New Orleans	$3 00

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* Without the aid of a large number of determinations of the specific gravity, there is always a certain degree of approximation which enters into the calculations for the tonnage of coal—even when a certain thickness of the bed is assured. When this report was first prepared, the only analyses to be obtained of this coal were those presented on page 13, and 1.339 was taken as the specific gravity—that being the result of four determinations by Dr D. D. Owen. It is deemed proper, therefore, to present the calculations based on that determination, as they were embodied in the original report. With a specific gravity of 1.339, a thickness of 2½ feet of coal would produce a fraction more than 4,023 tons to the acre, or 16,095,658 tons for 4,000 acres. Assuming 3 feet as the thickness of the bed, 3,250 acres would produce 15,833,250 tons of coal; and, according to this calculation, the coal would last 316 years, with a yearly yield of 50,000 tons.

The cost of handling and selling the coal at New Orleans was not learned. It may be confidently estimated, however, that $3.25 the ton will fully cover all manner of expenses which may be incurred in mining and vending the coal. It is not improbable, indeed, that it is an overestimate.

The cost of carriage from New Orleans to Liverpool was not definitely learned. It is believed, however, judging from information received from Mr. Wm. Creevy, of New Orleans, that, at certain seasons of the year, the coal may be landed at Liverpool, direct from the mines, at a total cost of from $5.25 to $6.25 the ton—possibly less.

It does not seem at all necessary, however, to look to England for the disposition of the coal. There is no reason why all that may be mined in a year may not be sold in this country—in the towns lying along the Mississippi river, in New Orleans, and in New York. In fact, its quality as a gas producer is such that, were it placed in the market, New York alone should consume a large proportion of the output.

ESTIMATES FOR THE INCOME.*

The coal may be carried to New York *via* New Orleans at a cost of about $5.00 the ton from New Orleans, or $8.25 the ton direct from the mines (including the cost of mining, etc.), and sold there for from $10.00 to $15.00 the ton—an average of $12.50.†

Were all the coal sold at the rate of $12.50 the ton, which is believed to be rather under than above an average price, there would be a net profit of $4.25 per ton. Multiplying this by 50,000, the assumed number of tons vended in a year, we obtain $212,500 as the annual income from the coal alone.

This simplified reads:

Gross returns from 50,000 tons, at $12.50 the ton	$625,000
Less cost, at $8.25 the ton	412,500
Total annual profit	$212,500

---

*This is a matter which is entirely estimative, and is of more value as a graphic illustration of the possibilities of the estate than as a strict mathematical fact. The estimate was made at the request of Col. Johnston.

†These prices fluctuate, of course; but a careful comparison of many "prices current" reports justifies this estimate.

To this may be added rental from some fifteen or twenty farms; not knowing the amount of income from them, however, it is not taken into consideration. Appended to this report is a letter from Mr. Creevy, of New Orleans, giving further information concerning the market price of cannel coal in Liverpool, New Orleans, and New York.*

Just at what sum the property is valued I am not informed. Supposing, however, that a capital of $500,000 be raised for its purchase, with the expectation of the purchaser recovering the amount in twenty-five years, the following would exhibit about the amount on which a yearly dividend might be declared:

Annual income from 50,000 tons of coal	$212,500
Less amount to be set aside annually (bearing interest at 6 per cent.) to reinstate the capital—about	18,875
Net income	$193,625

This would be about 38.7 per cent. on the original capital.†

VI.

THE MINES.

The mines from which the coal used by the Breckinridge Coal and Oil Company was taken are located near the centre of the property, at Bennettsville—the name given to the mining village about eight miles southwardly from Cloverport.

There are at this place eleven dwellings worthy of restoration; to do which would cost, on an average, $200 to each house—making a total of $2,200 as the cost for repairing the eleven.‡ In addition to these dwellings, there are (at the mines) an engine-house, in good order, with stalls for two engines; an office, a scales-house, a large building used for a school-house and "lodge-room," and a barn and stables for the bank mules.‡

At the factories, on the river, there is a cottage used by the superintendent, valued at $2,500; a tenement row, valued at

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*See Appendix "A."

†The actual amount of coal mined in a year may, and very probably would, fall very short of 50,000 tons. It will be understood that such a basis for calculation is used altogether for convenience, the actual yield being determined entirely by circumstances.

‡See Appendix "B."

$5,000; and "Cairn's Castle" (a dwelling which cost in its unfinished condition $11,000), valued at $5,000. The remaining buildings and materials are, under the circumstances, valued at no more than $2,000.

The mines were connected with the river by a broad-gauge railway, seven and a half miles in length. The line is now in a very poor condition, the trestling and cross-ties having rotted away. The road-bed, however, is in comparatively good order, requiring but little work to make it ready for a narrow-gauge track. The track as originally constructed was a poor affair, consisting merely of wooden stringers, banded with iron, laid across the cross-ties. It will be seen that the estimate for rebuilding the road calls for no articles but those of the best quality.*

The mines consisted of sixteen (16) adits driven in the hill high above water level; only one is now working, and that chiefly for the purpose of supplying steamboats with coal for torches, etc. Taking into consideration the length of time they have lain without attention (nearly fifteen years), the entries are in a fair condition; many of them, so far as may be seen, needing but little work to reopen them. Some, however, are choked up with débris which conceals their interior condition. As the roof is a sand rock, however, it is believed that most of the material has come from near the entrance, and that further back the entries are comparatively clear. Water was standing in nearly all of the drifts (except the one now working), kept there by the banked up débris at their mouths. From all that could be gathered concerning it, it would seem that the question of drainage is of small moment, as the entries are so located that they may be kept clear of water with comparative ease.

THE COST OF REOPENING THE ENTRIES, ETC.

The cost of reopening the mines and arranging everything in working order once more would be about as follows:†

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*See Appendix "C."

†See Appendix "C" in part.

Reopening fourteen entries, at $100 each	$1,400
One hundred bank cars restored	1,500
One pair track scales	1,000
Repairing incline and drum-house	1,500
Repairing ten houses at the mines	2,000
Hoisting engine and rigging for drum-house	4,500
Re-establishing the railroad	83,617
Incidentals	1,000
Total	$96,517

Reference is made to the careful estimate prepared by Captain William H. Pitts, which is appended to this report, for the details required in rebuilding the railroad.

In conclusion, it may be stated that, although this statement may seem crude in some of its parts—due in a large measure to the limited time that was allowed wherein to collect data—it has been the endeavor to give no more than simple facts concerning the property. I was not so fortunate in obtaining estimates as was desired and expected; accordingly, those given may not be so complete as possibly may be generally desired.

APPENDICES.

APPENDIX A.

LETTER FROM WILLIAM CREEVY, ESQ.

"New Orleans, October 19th, 1875.

"Dear Sir: * * * * With regard to the selling price of coal in England, would say that it varies very much, as there are such a variety of qualities. The article known as 'English Cannel,' which assimilates very much in character to the 'Breckinridge,' sells at 16 sh. and 20 sh. per ton; and freight from Liverpool ranges from 12 sh. to 15 sh. per ton. The article is not in general use in this market on account of the price; it usually commands $12 to $15 per ton. With regard to the cost of transportation of coal to England, would remark, that I have never known a shipment from this country, although freight could doubtless be had at some seasons of the year, for the purpose of ballast, at $2 and $3 per ton.

"While agent for the 'Breckinridge Coal Company,' in 1853–'6, I shipped several cargoes of the coal to New York, at freight of $5 per ton; and the coal sold in that market for fuel purposes and as enricher of gas for $15 per ton and upwards.

"Since 1857, no Breckinridge coal was received at this point, and, in fact, no shipments were made from the mines. The company considered the coal too valuable for fuel purposes, and their attention was given to the manufacture of oil, etc. The coal in this market commands about the same price as English cannel, and I sold large quantities at $10, and in some instances, when the stock of coal was low, at $12 and $15 per ton.

"This market is now almost exclusively supplied with Pittsburgh coal, and the consumption of last year was put at 375,317 tons. The price depends very much on the supply, which is governed by the stage of water in the Ohio river. The average price for the past two years, at wholesale, about $4 per ton; at retail, about $6.50 and $7 per ton.

"Having lost all the books and memoranda connected with my agency of the 'Breckinridge Coal Company,' I am unable to furnish you with particulars. * * * * *

"Yours truly,

[Signed] "WM. CREEVY."

APPENDIX B.

LETTER FROM CAPTAIN WM. H. PITTS.

"CLOVERPORT, KY., September 24th, 1875.

"*Mr. C. J. Norwood:*

"DEAR SIR: I am in receipt of your favor of the 20th inst., and respond just as soon as I have been able to obtain answers to some of your questions; and regret that I can offer but meagre information.

"As regards your first question,* I can give you no figures. Major Atkinson and myself both endeavored last year to get data upon which to base an estimate of the amount taken from the mines, but such information as we did get was obtained by leading questions put to parties whose answers I considered only guess-work, although Major Atkinson made therefrom a map, which should be with those you have, and will give you as accurate an idea as anything I can give you.† You saw the condition the entries were in, and will readily see that at present a survey cannot be made.

"A list of articles at the oil works would require the work of two men a number of days to make, and avail little after it is made. The value of such old material as now remains is simply the amount it would bring if sold as such. All the carpenters here are, at present, engaged in the construction of a large tobacco warehouse, and I have not been able to get one of them to go to Bennettsville to make the estimate you desire; besides, I do not think any one of them is capable of giving an accurate opinion about the repairs necessary.

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*This concerned the amount of coal that had been removed from the mines.—C. J. N.

†This map I found to be not of very practical value.—C. J. N.

"There remain at the mines, at present, some eleven dwelling-houses worthy of restoration. Three of these are occupied, and I believe, as an average, less than $200 each will place them in good repair. Besides these there is an engine-house, with stalls for two engines, which is in good order; also an office, scales-house, a large building used as a school-house and lodge-room, and a barn and stables for the bank mules.

"The Superintendent's cottage is valued at $2,500; the tenement row was only partially finished originally; now some seven of them are worth say $500 each, and as many more $300 a-piece. The other buildings at the works are not adapted to other use than the one they were intended for, and I therefore think, in view of their present condition, they are most valuable as old material, and as such are probably worth $2,000. The building known as the 'Castle' was not entirely finished when the work upon it was suspended; up to that time it had cost $11,000, I am told. Although it might not sell for so much, I believe it is worth $5,000 to any one who could spend $2,000 in repairs to it.

"In addition to the coal lands, of which you have maps and areas, the company owns the right of way for a railroad from Bennettsville to Cloverport, some seven miles in length, and fifty feet on each side of the centre line of the road.

"At the river there are some twenty-seven acres of land, to which must be added the castle lot, containing eight more. There are some fifteen or twenty farms in the outlying lands, the buildings upon which are log-houses, with necessary barns and outbuildings, the value of which we cannot estimate.

"There has never been a survey made of the cultivated lands, and I can't tell the number of acres they contain, nor have I had time to go and make an approximation.

"Since receiving your letter, I have talked with several miners, and they all agree in saying that, on the eight hour system, one ton per day to the man is about as much as can be relied upon for each miner to average.

"The price I am now paying is $1.60 per ton, the miner delivering the coal outside. I send you inclosed a copy of the railroad estimate; you will find therein some answers to your questions.

"The gauge of the old road was four feet eleven inches, and of course any one under this can be adopted, and will not change materially the aggregate amount.

"The prices affixed for iron, spikes, cars, engine, etc., are quotations from reliable firms, and are of late date; and the other prices are rather over than under, and everything to be first-class of its kind. There are one or two items omitted, for the reason that we can supply them from what we have on hand.

"Regretting my inability to give you more accurate answers, * * * * * * *

"Respectfully yours,
[Signed] "WM. H. PITTS."

APPENDIX C.

ESTIMATE OF COST OF RE-ESTABLISHING THE CLOVERPORT COAL AND OIL COMPANY'S RAILROAD, ETC.

8 miles grading, ditching, and surfacing, at $500 per mile	$4,000
19,000 cross ties, at 20 cents each	3,800
17,000 cubic yards of stone ballast	8,500
3,700 lineal feet of trestling, at $3 per lineal foot	11,100
43 culverts restored, at $50 each	2,150
380 tons T rails, 30 lbs. per yard, at $56 per ton	21,280
3,168 fish-bar joints, at 60 cents each	1,908
297 kegs of rail spikes, at $7 per keg	2,079
35 coal cars, at $200 each	7,000
2 flat cars repaired, at $200 each	400
1 locomotive engine, delivered	7,500
100 bank cars restored, at $15	1,500
2 turn-tables	1,500
Laying track	1,500
Water-tanks	1,900
Track scales	1,000
Repairing incline and drum-house	1,500
Reopening entries to mines, at $100 each	1,400
Repairing 10 houses at mines, at $200 each	2,000
Engineering expenses	3,000
Engineering instruments, stationery, etc.	1,000
Contingencies, freights, etc.	5,000
Total	$91,017

[Signed] WILLIAM H. PITTS, C. E.

APPENDIX D.

TABLE OF SPECIFIC GRAVITIES OF COAL, WITH COMPUTATIONS FOR THE CORRESPONDING NUMBER OF TONS IN ONE ACRE AND ONE HUNDRED ACRES.* PREPARED BY C. J. NORWOOD.

Specific gravity.	1 acre.	100 acres.	Specific gravity.	1 acre.	100 acres.
1.01	1,227.55	122,755	1.21	1,470.63	147,063
1.02	1,239.70	123,970	1.22	1,482.78	148,278
1.03	1,251.86	125,186	1.23	1,494.94	149,494
1.04	1,264.01	126,401	1.24	1,507.09	150,709
1.05	1,276.17	127,617	1.25	1,519.25	151,925
1.06	1,288.32	128,832	1.26	1,531.40	153,140
1.07	1,300.47	130,047	1.27	1,543.55	154,355
1.08	1,312.63	131,263	1.28	1,555.71	155,571
1.09	1,324.78	132,478	1.29	1,567.86	156,786
1.10	1,336.94	133,694	1.30	1,580.02	158,002
1.11	1,349.09	134,909	1.31	1,592.17	159,217
1.12	1,361.24	136,124	1.32	1,604.32	160,432
1.13	1,373.40	137,340	1.33	1,616.48	161,648
1.14	1,385.55	138,555	1.34	1,628.63	162,863
1.15	1,397.71	139,771	1.35	1,640.79	164,079
1.16	1,409.86	140,986	1.36	1,652.94	165,294
1.17	1,422.01	142,201	1.37	1,665.09	166,509
1.18	1,434.17	143,417	1.38	1,677.25	167,725
1.19	1,446.32	144,632	1.39	1,689.40	168,940
1.20	1,458.48	145,848	1.40	1,701.56	170,156

APPENDIX E.

ANALYSES OF VARIOUS CANNEL COALS.

Following are analyses of several cannel coals, some of them being well-known ones, for comparison with those made of the Breckinridge coal:

Number of analysis	1	2	3	4
Moisture	1.50	1.20	3.53	0.94
Volatile combustible matter	52.20	58.80	48.30	52.38
Fixed carbon	40.60	35.30	42.39	35.54
Ash	5.70	4.70	5.78	11.14
Total	100.00	100.00	100.00	100.00
Coke	46.30	40.00	48.17	46.68
Sulphur	0.780	not est.	not est.	1.423
Specific gravity	1.306	1.180	not est.	1.280
Analyst	P. and T.	P. and T.	C. and B.	P. and T.

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*The thickness of the coal is reckoned at one foot, and the ton used is the one of 2,240 pounds. The table will also serve for other materials than coal.

Number of analysis	5	6	7	8
Volatile matter*	43.37	49.6	70.10	58.52
Fixed carbon	46.50	41.3	10.30	25.28
Ash	10.13	9.1	19.60	14.25
Total	100.00	100.0	100.00	98.45
Specific gravity	1.27	1.228	not est.	1.1831
Analyst	Johnson.	. . . . .	Gesner.	. . . . .

* Includes "moisture." Sulphur not determined.

Analysis No. 1 is of the "Hunnewell" cannel, Kentucky; No. 2, Frozen Creek cannel, Breathitt county, Kentucky; No. 3, Saline county, Missouri, cannel (used at the St. Louis gas works), analyzed by Chauvenet and Blair; No. 4, George's Branch cannel, Breathitt county, Kentucky; No. 5, Kanawha cannel, Virginia; No. 6, Lesmahago cannel, Scotland; No. 7, Boghead cannel; No. 8, Weym's cannel.

All analyses indicated as made by "P. and T." were made by Dr. Robert Peter and Mr. John H. Talbutt, Chemists for the Geological Survey.

For proper comparison with the last four analyses, it should be remembered that the total volatile matter indicated in the analysis of the Breckinridge coal amounts to 60.90 per cent., or 9.20 per cent. less than in the Boghead cannel coal.

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